THIRD REPORT

National Steering Committee for Application of Pesticides - Western Defoliators

January 30, 1991

USDA Forest Service
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CONTENTS

I. INTRODUCTION

The third meeting of the National Steering Committee for Application of Pesticides - Western Defoliators met in Salt Lake City, Utah, November 6, 1990. The meeting was held in conjunction with the National Steering Committee for Application of Pesticides - Gypsy Moth and Eastern Defoliators.

A. Committee Members

J. Robert Bridges	WO/FIDR (Washington, DC)
Jesus Cota	WO/FP (Washington, DC)
John Cunningham	Forest Pest Management Institute (Sault Ste. Marie, Ontario)
Gary Daterman	PNW/FIDR (Corvallis, OR)
Kees van Frankenhuyzen 1.	Forest Pest Management Institute (Sault Ste. Marie, Ontario)
Ladd Livingston	Idaho Department of Lands (Coeur D'Alene, ID)
John Neisess	R-5(RO)FPM (San Francisco, CA)
Max Ollieu	R-6/FPM (Portland, OR)
Iral Ragenovich	R-6(RO)FPM (Portland, OR)
Pat Shea	PSW/FIDR (Davis, CA)
Larry Stipe	R-1(RO)TM (Missoula, MT)
Julie Weatherby	R-4(BFO)FPM (Boise, ID)
Jack Barry (Chairperson)	WO/FPM (Davis, CA)

1. Absent

B. Other Participants

Dave Bridgewater	R-6/FPM (Portland, OR)
Leo Cadogen	Forest Pest Management Institute (Sault Ste. Marie, Ontario)
Harold Flake	R-8/FPM (Atlanta, GA)
Michelle Frank	NA/FPM (Durham, NH)
Tom Hofacker	WO/FPM (Washington, DC)
Dave Holland	R-4/FPM (Ogden, UT)
Win McLane	USDA/APHIS (Otis AFB, MA)
Mike McManus	NES/FIDR (Hamden, CT)
Dick Reardon	NA/AIPM (Morgantown, WV)
Jessie Rios	California Department of Forestry (Sacramento, CA)
Harry O. Yates III	SEFES/FIDR (Athens, GA)

These participants were encouraged to share with the committee their concerns and needs related to managing gypsy moth.

C. Purpose of Steering Committee

The purpose of the steering committee is to analyze, identify, and recommend field and pilot testing needs for application of pesticides to manage western defoliators. Needs include those associated with pesticides, application systems, techniques, and strategies that influence the USDA Forest Service's (FS) and and State cooperator's ability to use pesticides safely, effectively, and in an economically, and environmentally acceptable manner.

D. Operating Guidelines

The committee expanded its scope as reflected in paragraph C above, to include use of ground application of pesticides to manage insects

that defoliate western forests. The committee will also serve, at the request of the Director, Forest Pest Management, as a panel to review national technology project proposals that relate to western defoliators. Additional operating guidelines adopted at the previous committee meeting are as follows:

1. Emphasize cooperation between FIDR and FPM especially in planning and conducting field projects.

2. Emphasize the need to field test new strains of *Bacillus thuringiensis* (B.t.) and not the HD-1 strain. The HD-1 strain has been adequately tested by FIDR; however, unique or unusual changes to HD-1 or its carrier may qualify it for testing.

3. Maintain the traditional approach to field testing and pilot projects.

4. Encourage thorough and timely reporting of field tests and pilot project results.

5. Facilitate cooperation with industry and encourage their development and testing of microbials.

6. Seek ways to reduce costs of field tests and pilot projects, and to encourage industry to share costs.

7. Maintain this steering committee.

E. Reports to the Committee

Reports delivered to the Committee by members and other participants are contained in the Appendix.

II. CURRENT RECOMMENDATIONS

Current recommendations are primarily recommendations carried forward from the previous meeting. Recommendations are listed in order of priority with No. 1 being the highest priority followed by the organization that the committee recommends as the lead to initiate action.

A. Laboratory and/or Investigations

1. **Pursue laboratory testing of new *Bacillus thuringiensis* (B.t.) strains.**

   New strains of B.t. that may have significantly higher efficacy against western defoliators should be tested in the laboratory in cooperation with industry, e.g. Novo and Abbott.

   PNW

2. **Develop a plan to obtain data on impact of B.t. on non-target organisms.**

   There is only limited information in this area and the committee recommends that a plan be developed by PNW to obtain these data. The plan would include field inventory, laboratory evaluations, field testing, and methods to fund and accomplish this work.

   PNW

3. **Explore techniques for rapid bio-assay of B.t.**

   ELISA (enzyme link immunosorbant assay) techniques are needed for rapid bio-assay of B.t. in the field. Capabilities exist at University of California, Davis (UCD) and Entotech, Inc., (Novo),

Davis, CA. The committee recommends that a proposal be prepared and funds be made available with Pat Shea taking the lead.

PSW

4. **Develop, identify, and evaluate improved carriers for TM Biocontrol-1.**

The current tank mix of field grade molasses, Orzan LS, and water handled well during January 1991 airport trails at Davis, CA. Atomization from Micronair atomizers and flat fan nozzles appeared to be excellent; however data are still being evaluated. Product Coordinators (Jim Hadfield for TM Biocontrol-1 and Dick Reardon for Gypchek) are cooperatively developing a 5-year plan that will lead to operational use of these insecticides. Investigating improved carriers and cooperation with Canada on carrier development should be part of the plan. The committee also recommends that the product managers seek cooperation from the private sector in developing improved carriers, especially Gypchek carriers as the potential use of Gypchek far exceeds that of TM Biocontrol-1.

R-6
NA
PNW

5. **Determine evaporation rates and physical properties of microbial tank mixes.**

MTDC is soliciting for a contractor to determine evaporation rates and physical properties of pesticide tank mixes used by the FS. Rates will be determined as funds are available; however MTDC should request funding pursuant to this recommendation.

MTDC

B. Field Tests

1. Field test TM Biocontrol-1 including lower doses, and with improved carriers as they become available. Priority is given to testing methods of controlling Douglas-fir Tussock Moth (DFTM) as the insect is in current outbreak.

   PNW

2. Conduct mating disruption tests using pheromones against western spruce budworm.

   PNW

3. Conduct cooperative field tests of several dosages (0.5, 1, and 2 ounces per acre) of Dimilin against DFTM and study non-target effects compared to non-target effects of B.t.

   PSW

C. Pilot Projects and Cooperative Field Tests/Pilot Projects

1. Conduct cooperative pilot test of TM Biocontrol-1, double (spring and summer treatments) against new, low level, and sub-outbreaks of DFTM.

   PNW

2. Conduct mating disruption tests using pheromones against DFTM.

   PNW
   R-4
   R-6

3. Conduct cooperative field tests/pilot tests of new strains of B.t. against western spruce budworm as they are recommended by PNW (Project 4502).

PNW
R-6

4. Conduct pilot test of B.t. against new and low level outbreaks of DFTM.

R-6

5. Conduct pilot test of Dipel 8L and Dipel 8AF applied at 32 ounces per acre to control western spruce budworm.

Abbott Laboratories

D. Equipment, Models, and Technology Development.

1. Evaluate the utility of the computer model Computer Assisted Spray Productivity Routine (CASPR) on a pilot or operational project.

R-4
WO/FPM
MTDC

2. Evaluate existing aircraft guidance systems and provide recommendations for operational deployment.

MTDC

3. Evaluate and recommend methods of sampling ultra low volume (ULV) sprays on pilot and operational projects.

MTDC

4. **Update and add spray nozzle specification data to the Program WIND aerial application equipment handbook.**

MTDC

5. **Determine physical properties and drag coefficients of substances.**

MTDC

6. **Coordinate complex terrain modeling with Global Positioning System (GPS), Geographic Information Systems (GIS), and expert system activities being developed by the FS.**

MTDC

E. Information and Administrative Management

1. **Plan and conduct multi-year monitoring, analyses, and data management of spray treatments.**

R-3
R-4
R-5
R-6

The data and information are needed for cost/benefit analyses by resource managers. We need to know duration of carryover benefits of treatments and tree growth information. Even short term benefits of treatment cannot be determined during the first year of treatment. For cost/benefit information and other economic analysis, the benefits or lack of benefits over 3 to 5 year periods should be established and recorded. This includes the R-6 Meacham Pilot Project conducted in 1988. Monitoring during 1989 shows that the benefits of treatment were carried over from 1988 to 1989. Monitoring the R-3 Jemez Mountain

control project showed that the western spruce budworm was kept suppressed for 5 years. This is valuable information in developing control strategies and in calculating cost/benefits for future control operations.

2. **Develop guidelines for conduct of wind tunnel and airport spray characterization trials.**

WO/FPM

3. **Pursue microbial research.**

WO/FIDR
WO/FPM
PNW

The committee recommends maintaining and increasing support of microbial and pheromone research for improved pest monitoring and suppression.

4. **Evaluate and revise current standards for determining successful control.**

FIDR/WO
FPM/WO

5. **Registered B.t. formulations.**

Currently registered B.t. products for DFTM and western spruce budworm, and their respective undiluted application rates for 16 BIU's per acre are listed below.

Product	Application Rate	Registration DFTM[1.]	Registration WSBW[2.]
Thuricide 32LV	64 oz	X	X
Thuricide 48LV	43 oz	X	X
SAN 415	64 oz	X[3.]	X[3.]
Dipel 6L	43 oz	X	X
Dipel 8L	32 oz	X	X
Dipel 6AF	43 oz	X[3.]	X[3.]
Dipel 8AF	32 oz	X[3.]	X[3.]
Foray 48B	43 oz	X[3.]	X[3.]

1. DFTM = Douglas-fir tussock moth.
2. WSBW = Western spruce budworm
3. Not registered for forestry use in California.

6. **The committee strongly endorses assignment of Product Coordinators for TM Biocontrol-1 and Gypchek.**

7. **The committee expresses concern over apparent failure of the DFTM pheromone early warning system to detect DFTM build-up in Idaho.**

III. STATUS OF PREVIOUS RECOMMENDATIONS

Status of previous committee recommendations is summarized below.

A. Laboratory and/or Field Investigations

1. Pursue laboratory evaluation of new B.t. strains.

PNW

No new strains were evaluated.

2. Develop a plan to obtain data on impact of B.t. on non-target lepidoptera.

PSW
PNW

The committee recommended that PSW and PNW join to obtain data on impact of B.t. on non-target leptidoptera. This was not accomplished.

3. Develop, identify, and evaluate improved carriers for TM Biocontrol-1.

PNW
R-6

Jim Hadfield, R-6, has been designated TM Biocontrol-1 product coordinator and is cooperating with Roy Beckwith. Jim's charge includes field evaluation of tank mixes. Tests will be conducted in early 1991 at the University of California, Davis wind tunnel to investigate atomization and influence of physical properties. Also, airport trials were conducted at Davis, CA to evaluate mixing, handling, and atomization of TM Biocontrol-1 and Gypchek. Results of these tests are being evaluated.

4. Explore techniques for rapid bio-assay of microbials.

PSW

Pat Shea has discussed with Bruce Hammock, University of California, Davis (UCD), the feasibility of using an enzyme link immunosorbant assay (ELISA) method of determining B.t. potency. The next step is to pursue funding and establish a cooperative project at UCD.

5. Determine evaporation rates and physical properties of microbial tank mixes.

WO/FPM

Bob Ekblad, MTDC, has prepared an RFP to contract a facility to measure evaporation rates and proposal responses will be reviewed in March. Physical properties of tank mixes are being measured at UCD for selected biological tank mixes.

6. Obtain spreadfactors for all micorbial tank mixes.

WO/FPM

The U.S. Army, Aberdeen Proving Ground, was contracted to evaluate B.t. spreadfactors on deposit papers. FPM (Davis) Report 90-8, <u>Spectroscopically Derived Spreadfactors for Different Bacillus thuringiensis Insecticidal Formulations on Paper Impaction Cards</u>. The report discusses utility of kromekote as an impaction surface and provides spreadfactors for Foray 48B and Thuricide 32 LV. Additionally Alam Sundaram and Errol Caldwell (FPMI) have been contacted about doing spreadfactors work for the FS. The latter is still under discussion. The pesticide laboratory at Pennsylvania State University determines spreadfactors for microbials and should be contacted for

spreadfactor information. Recommend that industry be encouraged to provide spreadfactors for their products using standardized methology.

B. Field Tests

1. Conduct field tests of new strains of B.t. against western spruce budworm as recommended.

   PNW

   No field tests were conducted in 1990 and none scheduled until 1992.

2. Conduct field tests of improved tank mixes of TM Biocontrol-1.

   PNW

   No tests due to lack of a qualifying population.

3. Conduct mating disruption tests using pheromones against western spruce budworm and (DFTM) outbreaks.

   PNW
   R-4

   Julie Weatherby and Lonnie Sower are cooperating on mating disruption test of DFTM moth on 200-500 acre blocks. PNW is planning DFTM test scheduled in 1991.

4. Conduct field experiments of Sandoz Crop Protection Corporation (Sandoz) product SAN 415 SC 32LV (NRD-12 strain, 32 BIU per gallon) against DFTM to obtain efficacy data.

   PNW

No field experiment was conducted and Sandoz has not demonstrated an interest in supporting forest spraying with SAN 415.

5. Conduct field experiments of lower doses of TM Biocontrol-1.

PNW

No field experiments were conducted as there were no test populations in the Northwest. A dosage rate test is scheduled in 1991.

6. Conduct cooperative field tests of several dosages (0.5, 1, and 2 ounces per acre) of Dimilin against DFTM in California.

PSW

No field tests were conducted as there were no test populations in California.

C. Pilot Projects and Cooperative Field Tests/Pilot Projects

1. Conduct cooperative pilot test of the Sandoz B.t. product SAN 415 against western spruce budworm.

PNW

No test of SAN 415 was conducted.

2. Conduct cooperative pilot test of TM Biocontrol-1, double (spring and summer treatments) against new, low level, and sub-outbreaks of DFTM.

PNW

No cooperative test of TM Biocontrol-1 was conducted.

3. Conduct pilot test of B.t. against new and low level outbreaks DFTM.

PNW

No test of B.t. was conducted against low levels of DFTM.

4. Conduct pilot test of Dipel 8L and Dipel 8AF applied at 32 ounces per acre to control western spruce budworm.

Abbott Laboratories

No test of low rates of Dipel 8L or Dipel 8AF were conducted.

D. Equipment, Models, and Technology Development

1. Conduct airport spray trails to characterize Dipel 6AF.

WO/FPM

Aircraft characterization trails of Dipel 6AF were conducted by WO/FPM (Davis), R-6/FPM and Abbott Laboratories at Marysville, CA in 1990 and results reported.

2. Evaluate and recommend methods of sampling ultra low volume (ULV) sprays on pilot and operational projects.

MTDC

No work was initiated.

3. Evaluate existing aircraft guidance systems and provide recommendations for operational deployment.

MTDC

MTDC has been asked to develop a proposal to address this recommendation.

4. Evaluate the utility of the computer model Computer Assisted Spray Productivity Routine (CASPR) on a pilot or operational project.

MTDC

Steve Munson (R-4) used CASPR to plan the 1990 R-4/Utah gypsy moth project. Evaluation of CASPR will be continued in 1991 on the R-4/Utah project.

5. Update reference reports on atomization of current pesticide tank mixes.

WO/FPM

WO/FPM (Davis) has published and distributed an update reference on atomization of pesticide tank mixes.

6. Update and add spray nozzle specification data to the Program WIND aerial application equipment handbook.

MTDC

MTDC has not initiated action on this recommendation.

7. Coordinate complex terrain modeling with Global Positioning System (GPS), GIS, and expert system activities being developed by the FS.

MTDC

WO/FPM (Davis), MTDC, and MAG met to discuss these needs and a feasibility report was prepared by FPM. Also, two meetings have

been held with EPA at Las Vegas to plan cooperative activities that include geographical and visualization techniques with EPA. An EPA/FS workshop is scheduled for June 1991. MTDC has a contract with Battelle to adopt a complex terrain model to FPM needs. Bob Ekblad prepared two status reports to the FPM technology task groups in August 1990. The project is progressing well.

8. Determine physical properties and drag coefficients of substances.

MTDC

MTDC has not initiated action on this proposal.

E. Information Management

1. Plan and conduct multi-year monitoring, analyses, and data management of spray treatments.

R-3
R-4
R-5
R-6

No action has been initiated.

2. Publish a reference and maintain a Data General computer data base on western defoliator aerial spray projects.

WO/FPM

WO/FPM (Davis) in cooperation with R-4/FPM has compiled and distributed a report entitled Aerial Insecticide Projects for Suppression of Western Defoliators: 1970-1989 - An annotated Bibliography.

F. Administrative

1. Guidelines for Field tests and Pilot Projects

   a. **Guidelines have been finalized and incorporated in the FS Handbook.**

   b. **No other guidelines have been prepared.**

2. West-wide EIS for DFTM.

   This was not done and committee does not believe it is necessary as EA's seem to accommodate this need.

3. Testing of NOVO's Foray 48B.

   The committee had suggested that NOVO pilot test Foray 48B. In that the material was pilot tested in 1990 a pilot test becomes somewhat academic.

IV. SUMMARY

The National Steering Committee for Application of Pesticides - Western Defoliators met in Salt Lake City, Utah, November 6, 1990. The April 1990 committee meeting recommendations were reviewed and discussed. Some progress on the recommendations has been made; however, the committee noted that progress is slow on most of the high priority recommendations. At the meeting previous recommendations were updated, expanded, and priorities changed as appropriate. The next meeting is proposed for early July 1991.

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APPENDIX

REPORT TO WESTERN DEFOLIATOR STEERING COMMITTEE MEETING, November 6-8, 1990.
G. Daterman, PNW-Station.

1990 ACTIVITIES:

1. R. Beckwith and D. Grimble have been evaluating a modified spray formulation for the DFTM virus (TM BioControl-1). Laboratory results are very good, but there is a need for testing the material in aircraft spray apparatus.

2. Field testing of trap design and modified lures for monitoring DFTM populations with pheromone-baited traps indicate that the standard (0.001%) pvc lure could be used in a commercially-available "USDA" trap for operational monitoring. This would simplify the process in comparison to the current use of the "milk-carton" trap. The Phero Tech lure was again compared in the field and found to be much improved in calibration of its release rate of pheromone (for avoiding premature trap saturation).

3. Western spruce budworm monitoring for prediction of defoliation levels was again conducted in Regions 1,2, and 6. Results were not available at the time this report was prepared. The PNW lead scientist for this work, C. Sartwell, retired September 28, 1990, but has assured Daterman that he will prepare a report and manuscript on the effectiveness of this technique.

4. Laboratory research on phytochemicals as feeding deterrents has turned up some promising leads for certain extracts and isolated compounds as effective feeding deterrents of the western spruce budworm and the gypsy moth. From a practical viewpoint, these materials would likely be useful for protection of ornamentals, rare (threatened and endangered spp) plants, nurseries, etc. Work is continuing on development of specific compounds.

1991 PlANS:

1. PNW/R6 has a joint proposal for Special Project Funding to evaluate a Mycogen Co. (San Diego, Calif.) set of BT strains and formulation against western spruce budworm. The proposal specifies screening tests in 1991 and field testing in 1992. R.Beckwith and D.Grimble are the PNW participants.

2. The upsurge of DFTM in NE Oregon and southern Idaho has prompted discussion and planning for field testing of lower dosages and new spray formulations for the nuclear polyhedrosis virus (TM BioControl-1). The dosage test would compare 1/4 and 1/2 dosages to the recommended label dose. Formulations would include comparisons of the Espro Co. modified molasses preparation to the label standard. Other promising candidate formulations should also be evaluated. This effort could be a combination field and pilot test project, with test variables evaluated appropriately between the respective efforts. R.Beckwith and D.Grimble are projected PNW participants.

3. The pending R4/R6 DFTM outbreak also prompted a study plan for pilot testing the pheromone mating disruption method of control for this pest. This

effort would be in cooperation with the appropriate Region, PNW, WO-FPM, and Scentry Inc. (Buckeye, Ariz.). Scentry and WO-FPM have been collaborating in their communications with the EPA to secure a 3-year EUP and eventually a full registration (for Scentry) for this control method on DFTM. Numerous past field tests have shown consistent efficacy for this technique on DFTM, and the the timing appears appropriate for a pilot test to evaluate operational feasibility and efficacy. L.Sower has prepared a draft study plan and would be the PNW participant.

4. Efforts to improve and further evaluate the pheromone-baited trap systems for monitoring DFTM and western spruce budworm will continue in 1991. This will include working with Phero Tech to refine and calibrate a commercial lure.

5. Research on feeding deterrents derived from plant extracts will also continue in 1991.

A Report to the USFS Joint Meeting of the National Steering Committee for Application of Pesticides - Western Defoliations, Gypsy Moth and Other Eastern Defoliations.

Salt Lake City, Utah 6th - 8th November 1990

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Research Activity: Impact and fate of insecticides in the envirolment.

Principal Researchers:

1. K.M.S. Sundaram - Distribution, Deposition and Persistance of *Bacillus thuringiensis* (*kurstaki*) [*B.t.*(k)] in a Deciduous Forest Enviroment.

Undiluted Novo Foray^R 48B *Bacillus thuringiensis* (k) formulation was sprayed in May 1990 over four blocks of a deciduous forest with oak stands in the Havley area of eastern Pennsylvania at two dosage rates in duplicate at 20 BIU/53 US oz per acre (50 BIU/1.57 L per hectare) and 30 BIU/80 US oz per acre (75 BIU/2.37 L per hectare). Prespray and postspray oak foliage and simulated oak foliage samples were collected at intervals of time and stored in alkaline buffer with NaN_3 for assaying the concentration levels of *B.t.*(k) (60 kilodalton, kDa) toxin. *B.t.* deposits in ground samplers (glass-fiber discs mounted on collection units and alkaline buffers in petri-dishes) were also collected at 1h postspray. Droplet densities (droplets/cm^2) and droplet size distributions (NMD, VMD, D_{max} and D_{min}) were measured at canopy and ground levels using Ciba-Geigy water sensitive papers (10 mm x 26 mm) mounted or fastened onto supports.

Gypsy moth larvae were bioassayed (force feeding) against the alkaline buffer extract of the formulation (Novo Foray^R 48B), and a calibration curve (% mortality *vs* concn. of 60 kDa) was prepared. Pre- and postspray *B.t.*(k) extracts of simulated and natural oak foliage) were bioassayed and the mortalities of the larvae determined. Using the calibration curve, the concentration of the 60 kDa *B.t.*(k) in the analytes were established. The concentrations of the 60 kDa *B.t.*(k) in different extracts were also quantified by using an enzyme-linked immunosorbent assay (ELISA) developed cooperatively by the author and Dr. D.B. Hammock (Univ. Calif., Davis, CA). The ELISA studies are in progress and involve the coating of the microtiter plates successively with goat anti *B.t.*(k), addition of analyte [*B.t.*(k) extract], addition of rabbit anti *B.t.*(k), goat anti-rabbit IgG (enzyme labeled) and developing a yellow color for spectroscopic quantification with the addition of a substrate. Using the bioassay and ELISA data, the distribution and persistence of *B.t.*(k) as 60 kDa will be evaluated. If efficacy data are made available, attempts will be made to correlate the residue levels with observed larval mortality.

Collaborative Research Areas:

The principal researcher will be pleased to interact with researchers interested in the above areas, *viz*; *B.t.* deposit assessment, *B.t.* quantification *via* bioassay and ELISA and evaluation of the persistence and fate of *B.t.* in a forest enviroment.

2. Stephen B. Holmes (Project Leader) and D.P. Kreutzweiser - Effects of B.t. on Non-Target Organisms.

B.t. is the most widely used forest pest control product in Canada. When it was still a minor component of forest spray programs, relatively little attention was paid to the environmental effects of B.t. Concern was focussed more on the chemical insecticides, such as fenitrothion, because these were perceived as being more damaging to the environment. Now, however, because of its increased use, B.t. is being looked at more closely.

At the Forest Pest Management Institute (FPMI), three studies that deal with the environmental impacts of B.t. spraying are underway. Each of these studies is described briefly below:

Toxicity of B.t. to Stream Insects

Relatively little has been published in the scientific literature on the toxicity of B.t.k. (Bacillus thuringiensis kurstaki) to aquatic insects. Eidt (1985) tested 9 taxa of aquatic insects, representing 4 major orders, Trichoptera, Plecoptera, Ephemeroptera and Diptera, for susceptibitliy to B.t. at concentrations of 4.3, 43 and 430 IU/mL under static conditions. The concentrations were chosen to represent a worst-case field situation, a 10X overdose and a 100X overdose, respectively. Only one species of blackfly was clearly affected by the B.t., and this was at the highest concentration. Although effects on other species were suggested, Eidt concluded that the risk to aquatic insects was low and that buffer zones were not required around water bodies for aerial spraying with B.t.k.

There are currently no buffer zones around standing water for aerial spraying with B.t. in Newfoundland, New Brunswick, Quebec and Ontario (Kingsbury and Trial 1987). Nova Scotia requires a 30 m setback for aerial spraying of all pesticides, including B.t. (Kingsbury and Trial 1987).

Recently, concern has been expressed by Environment Canada, Conservation and Protection, in British Columbia that the data base for B.t. is too limited to adequately assess the requirement for buffer zones around fishery sensitive streams. They suggest that further testing is needed, and that, until the information from these tests is available, a buffer zone of 10 m should be imposed.

In order to fill one of the data gaps identified by Environment Canada (i.e. the need for more comprehensive and reliable toxicity data), FPMI is conducting laboratory and field bioassays with B.t. and stream insects. The apparatus used in the laboratory tests is a flow-through design (Rodrigues and Kaushik 1984) that more closely simulates the natural stream environment than the static system of Eidt (1985). The initial test for each species is performed at 100X the expected environmental concentration (EEC) as calculated by the Department of Fisheries and Oceans Canada (i.e. 100 X 6 IU/mL). The total exposure and observation periods are 24 and 216 h, respectively. If a positive response is observed at this concentration, an additional test is conducted to determine the LC50. Field bioassays are performed in artificial stream channels. These tests concentrate on a sublethal response (i.e. induced drift) to the insecticide. The concentrations tested are arrived at in the same way as in the laboratory tests, except that an EC50 is calculated. The exposure and observation periods are 2.5 and 168 h, respectively. To date, 6 species

have been tested using this approach (Heptagenia flavescens, Stenonema sp., Isonychia sp., Isogenoides sp., Acroneuria sp., and Hydropsyche sp.), and no lethal or sublethal effects have been detected at 100X the EEC.

3. Principal Researcher: Kevin Barber - Relative Susceptibility to B.t. of Non-target Lepidoptera Larvae.

According to Dimond and Morris (1984), the larvae of 200 species of Lepidoptera are known to be susceptable to B.t.k. In addition, field studies have shown that B.t. spraying to control forest pests can signfficantly reduce populations of non-target Lepidoptera (Bendell 1986, Miller 1990). Lepidoptera are ecologically important because they function in food webs as herbivores and because they are a food resource for birds and other wildlife (Miller 1990). Lepidoptera are also esthetically valuable to amateur and professional naturalists and entomologists.

Studies at FPMI with B.t. and non-target Lepidoptera have focussed primarily on the caterpillar fauna of blueberry (Vaccinium angustifolium). These caterpillars are an important food resource for grouse, songbirds and small mammals in jack pine plantations. The relationship between B.t. spraying to control jack pine budworm and secondary effects on non-target wildlife was initially explored by J.F. Bendell of the University of Toronto (Bendell 1986, Innes and Bendell 1989), and some field work described below was conducted cooperatively with him.

In 1989, two 80 ha blocks of jack pine forest near Gogama, Ont. were aerially sprayed with B.t. Effects on blueberry leaf-feeding Lepidoptera were assessed in two ways: 1) larval populations were sampled by sweep netting along transects in treated and control areas, before and after spraying; and 2) field bioassays were conducted in which Itame brunneata (Lepidoptera: Geometriadae) larvae, one of the most abundant caterpillar species on blueberry at the time of treatment, were fed blueberry foliage collected from sprayed and unsprayed areas. Preliminary results suggest that caterpillar numbers were reduced on blueberry for up to 15 days after treatment. Results for individual taxa are not yet available. In the bioassays, mortality rates for Itame brunneata were in the range of 28-41%.

In addition to the studies described above, laboratory bioassay protocols are being developed for non-target Lepidoptera larvae. This includes establishment of laboratory cultures of important species. Attempts to rear Itame brunneata have met with only limited success so far. Better progress is being made with some other common species from blueberry (e.g. Orthosia revicta (Lepidoptera: Noctuidae)). In the laboratory bioassays, a number of dosing procedures are being investigated, including direct oral intubation and feeding of contaminated leaf disks and diet plugs.

Principal Researcher: R. Millikin - Secondary Effects of B.t. Spraying on Forest Songbirds.

Lepidoptera larvae are the preferred food for most breeding insectivorous forest birds (MacArthur 1958, Holmes and Schultz 1987), and are important for the growth and survival of the young of omnivorous species (Petersen and Best 1986, Johnson and Boyce 1989). By reducing the availability of caterpillar prey, B.t. spraying could indirectly affect forest birds.

In 1989, a study was conducted to determine the effect of B.t. spraying on the reproductive success of ground-nesting songbirds in jack pine plantations. This study took place in the same blocks as the caterpillar work described above. The methods used included singing-male censuses, observations of foraging behavior and feeding of young, collection of food samples from ligated nestling, determination of nestling growth rates and survival, and mist-netting of banded individuals.

The results are preliminary, but the following general observations can be made. Fewer food items were brought to hermit thrush young in the treated areas than in the control areas (4.8 versus 6.8 items/crop sample, respectively), and Lepidoptera larvae made up a significantly smaller component of the diet of treated nestlings (7% of food items versus 58% in control). These differences in diet did not translate into differences in growth rate or survival of nestlings (the probability of survival in the treated area was 0.40 and in the control was 0.23). The results were generally similar for other ground-nestling bird species (i.e. junco, white-throated sparrow and black and white warbler). Considering ground-nesting birds as a group, there was no significant difference in the proportion of young caught by mist-netting in the treated versus the control areas (21% and 25% of the total catch, respectively), or in the ratio of young to adult females. It is concluded that the observed reduction in caterpillar food resulting from the B.t. spray did not have a significant adverse effect on the growth or survival of young ground-nesting songbirds.

The studies described above are ongoing within the Environmental Impact Project of FPMI. David P. Kreutzweiser is responsible for aquatic toxicology studies, Kevin N. Barber for non-target Lepidoptera bioassays and Rhonda L. Millikin for forest songbird studies.

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Collaborative Research Areas: (Contact the project leader - S. Holmes)

1) Laboratory and field toxicity testing of forestry pesticides (hexazinone, trichlopyr and B.t.) on non-target aquatic invertebrates in flow-through systems.

2) Development of standardized methodologies to test the side-effects of pesticides on beneficial terrestrial arthropods. Establishing laboratory cultures of non-target Lepidoptera and conducting bioassays with B.t. and gypsy moth NPV.

3) Secondary effects of B.t. spraying on forest songbirds.

4) Development of microcosms to study the fate and environmental effects of microbial forest pest control products in the laboratory.

Research Activity: Control of Eastern Defoliations

Principal Researcher: A. Sundaram - Research Studies on Physicochemical Aspects of Pesticide Performance (conducted in 1990).

During 1990, the Pesticide Formulations Project at FPMI undertook two field studies, and two laboratory studies to examine (i) the influence of physicochemical properties of the end-use mixtures on droplet size spectra of the spray cloud, droplet spreading on foliage, and deposits on glass plates; and (ii) the rainfastness of foliar deposits of B.t. and glyphosate formulations.

Field Studies:

<u>Effect of Droplet Size and Cumulative Rainfall on Rainfastness of Foray 48B deposits on balsam fir foliage under field conditions</u>:

A small scale field study was conducted using the single tree treatment technique to determine the rain-fastness of foliar deposits of <u>B.t.</u> as determined by spruce budworm bioassay using 4th instar larvae. Foray 48B was diluted with water and sprayed over balsam fir seedlings (about 1 m high) at a dosage rate of 32 BIU in 4 L per ha, using a spinning disc atomizer, Micron Flak^R, calibrated to gerenate a narrow drop size range with an NMD of 80 um and a VMD of 86 um. Drops were counted on fully flushed needles and drops per sq. cm were evaluated.

Simulated rainfall of two different drop size spectra (almost monosized drops), with VMD values of 250 and 400 um, and two different cumulative rainfalls of 1 and 3 mm, were generated using Micron Herbi^R, and applied onto the seedlings at 24 h after <u>B.t.</u> application. Foliar branch tips containing fully flushed young buds were collected at different intervals of time up to 14 d after <u>B.t.</u> treatment, for bioassay using laboratory reared spruce budworm larvae. Mortality was assessed daily, and body weight depression once in two days, for a period of 14 days after treatment.

A comparative evaluation of the data on post-spray (within 15 min after application) and pre-rain samples (i.e., those collected at 24 h post-treatment) indicated that about 30% of <u>B.t.</u> activity was lost in 24 h after application. <u>B.t.</u> deposits were washed off under both intensities of rainfall, but wash-off was significantly higher at 3 mm than at 1 mm rain. Cumulative rainfall influenced <u>B.t.</u> wash-off from fir foliage much more than the droplet size of rain. Body weights were more depressed and mortality was higher in insects fed with buds collected before the rainfall, than with those collected post-rain. The data will be used to develop a model to understand the inter-relationships between size and impact velocity of rain drops, cumulative rainfall, and <u>B.t.</u> wash-off from balsam fir foliage.

Body weight depression and bioassay results on samples collected up to 14 d after treatment from seedlings that received no rain indicated that initial loss of <u>B.t.</u> activity was rapid within two days after treatment (a loss of about 50% of the deposited amount) but further loss was relatively slow. Measurable but very low <u>B.t.</u> activity still persisted for up to 9 to 10 d after treatment. This was detectable both by body weight depression and by low larval mortality. Further studies are on the way to understand the mechanism of loss of <u>B.t.</u> activity from treated foliage.

Collaborative Research Areas: The principal researcher will be willing to collaborate with USFS researchers in the following areas:

1) Factors contributing to the rainfastness of pesticides (e.g. droplet size and formulation properties)

2) Pesticide mechanisms.

2) Principal Researcher: Leo Cadogan - Efficacy of Dipel 352 (Dipel 16L) against spruce budworm.

A trial was conducted in NW Ontario to determine the efficacy of Dipel 352 (Dipel 16L) against fairly high (25 to 62 larvae/45 cm branch) populations of spruce budworm. The B.t. was sprayed undiluted at 30 BIU/ha (0.9 l/ha) and the budworm responses were examined on black spruce *Picea mariana* and balsam fir *Abies balsamea* species with widely different phenological developments.

One treatment matched the development of balsam fir (= peak budworm L_4) and the other block was sprayed 9 days later to match black spruce's development (= peak L_5). Results indicate that when the spray was timed to suit balsam fir development, budworm population reduction was less on both host species than when it was timed to suit black spruce.

In both blocks, defoliation was not different from that in the control. This suggests that these treatments were not effective against high budworm populations in protecting host tree foliage.

Areas of Collaborative Research: The principal researcher would like to collaborate with USFS researchers in the following areas:

1) Experimental design, methods and evaluation of aerial field trials.

2) Spraying and block marking techniques.

3) Responses of defoliations to insecticides.

3) Principal Researchers: Kees van Frankenhuyzen and Vince Nealis

a) Dose acquistion of B.t. by spruce budworm in relation to larval development, foliar deposits and persistence and weather conditions.

b) Foliar persistence of aerially applied B.t. on balsam fir in relation to weather conditions.

c) The influence of B.t. application timing on the survival of some spruce budworm parasitoids.

This research was conducted simultaneously with the efficacy trial. The results are currently being analyzed. Contact Kees van Frankenhuyzen or Vince Nealis for further information.

3) Principal Researcher: B.V. Helson - Insecticide Toxicology

a) New Insecticide Development

We have been assessing the potential of 4 new insecticides for the control of forest defoliators; alpha-terthienyl, RH5992, abamectin and its semi-synthetic derivative, MK-243 in the laboratory. Alpha-terthienyl, a natural phototoxic compound from members of the plant family, Asteraceae, has prevouslyy been tested on spruce budworm, jackpine budworm, eastern hemlock looper, forest tent caterpillar, white-marked tussock moth, and black army cutworm in collaboration with Dr. J.T. Arnason and A. Ceccarelli, U. of Ottawa and Dr. W.J. Kaupp, FP.I. In 1990 alpha-terthienyl was evaluated on gypsy moth larvae, but further tests are needed to confirm its toxicity. To date, all tests have been topical applications followed by exposure to near-UV light. We plan to asses its toxicity to SBL and EHL by ingestion and crawling contact exposure.

RH5992 is a novel insect growth regulating compound discovered by Rohm and Haas and under development bythemm. Dr. A. Retnakaran, FPMI, and I have been evaluating this compound against several forest lepidopteran defoliators. I have examined its toxicity to spruce budworm, eastern hemlock looper and gypsy moth larvae by direct contact and on sprayed foliage as well as its effects on feeding rates. In addition, the effects of exposure period on toxicity and the residual toxicity of RH5992 are being investigated.

Abamectin has been isolated from a soil microorganism, Streptomyces avermitilis by the Merck Sharp and Dohme Research Laboratories and is now registered as an miticide in the USA. MK-243, a semi-synthetic derivative of abamectin, has recently been developed and is reported to have very high activity to Lepidoptera. We have just begun testing MK-243 on SBL and EHL in comparison with abamectin. It appears to be very potent to these pests. We pln to expand our screening program against several other forest pests including gypsy moth.

b) White Pine Weevil

For several years we have been assessing the potential of pyrethroids, particularly permethrin, for the control of WPW adults in the laboratory with encouraging results. In 1990, P. deGroot, FPMI, and I collaborated in conducting a field trial to assess the effectiveness of permethrin in protecting leaders of jackpine from weevil attack. Leaders were sprayed by hand with dosages of 70 and 140 g AI/ha in early spring. Methoxychlor was sprayed at 1 kg/ha as a standard for comparison.

c) Pine False Webworm

In 1990, D.B. Lyons, Forestry Canada, Ontario Region, and I collaborated in laboratory and field trials to develop an insecticide control strategy for the pine false webworm on red pine. Laboratory bioassays with 10 common, rgistered insecticides were carried out with newly hatched larvae on sprayed red pine branches. Field trials were then conducted with Ambush 500EC (permethrin) at 35, 70 and 2 x 35 gAI/ha, and Sevin XLR Plus (carbaryl) at 12, 250, 500 and 2 x 125 gAI/ha applied by mistblower in a red pine plantation.

d) Seedling Debarking Weevil

For the past three years we have been conducting insecticide bioassays with Hylobius congener adults in cooperation with Bruce Pendrel, Foresty Canada, Maritimes Region. The residual effectiveness of permethrin, chlorpyrifos and fenitrothion for protecting conifer seedlings for up to 2 years is being evaluated by spraying or dipping potted white spruce and red pine seedlings with selected concentrations of these insecticides, placing the seedlings outdoors and exposing weevils to them at yearly intervals.

e) Other Pests

We recently completed field trials to determine the efficacy and optimum timing of permethrin for the control of spruce budmoth, Zeiraphera canadensis larvae in cooperation with M. Auger, Quebec Ministry of Energy and Resources. We are currently screening insecticides against Conophthorus cone beetles in collaboration with P. deGroot. We also conducted preliminary insecticide bioassays on black headed budworm, Acleris variana this year.

Collaborative Research Areas: The principal researcher is willing to collaborate in laboratory and field studies relating to these or other promising new products and to the development of insecticide control stratagis for the above pests and others of potential importance in Canada if resources and time permit.

4) Principal Researcher: John C. Cunningham - Virus Application Project

a) Gypsy Moth

Most of the activity of the virus application project has been focussed on gypsy moth for the last 3 years. A registration petition for Disparvirus, the name given to our Canadian product, was submitted in April 1990 and is currently being evaluated. Much of the data in this package were obtained from the Gypchek registration petition.

In 1988, a double application of Disparvirus at 1.25×10^{12} PIB/ha (total 10^{12} PIB/ha) in an emitted volume of 10.0 L/ha using an aqueous tank mix gave excellent results when applied on first instar larvae. However, this dosage and emitted volume are both considered to be too high for operational use. In 1989, a double application of 5×10^{9} PIB/ha (total 10^{12} PIB/ha) was tested at 10.0 L/ha and 5.0 L/ha on first instar larvae. The aqueous tank mix contained 25% molasses, 10% Orzan LS and 2% Rhoplex B60A sticker. The lower dosage was also deemed to be satisfactory. Hence the recommendation for Disparvirus application was changed to a double application of 5×10^{11} PIB/ha in 5.0 L/ha.

In 1990, a further reduction in emitted volume to 2.5 L/ha was tested and compared to 5.0 L/ha using the aqueous tank mix. Results with 2.5 L/ha were not as good as 5.0 L/ha, so a further reduction in emitted volume is not recommended when using this aqueous tank mix. A trial was also conducted during the 1990 season, with Gypchek, which was supplied by USDA Forest Service colleagues. The dosage was a double application of 5×10^{11} PIB/ha (total 10^{12} PIB/ha) in 5.0 L/ha using an emulsifiable oil tank mix. Larvae were mainly in the first instar at the time of application. The tank mix contained 25% Dipel 176 blank carrier vehicle and 75% water. Excellent results were obtained and it is suggested that this tank mix and dosage be tested at an emitted volume of 2.5 L/ha.

A commercial source of gypsy moth viral insecticide is vital if it is going to be used operationally in Ontario. FPMI is negotiating with Espro and several funding agencies with a view to establishing a pilot plant in the Institute and eventually a production facility in Sault Ste. Marie.

b) Douglas-fir Tussock Moth

A Canadian viral insecticide for Douglas-fir tussock moth called Virtuss and the USDA Forest Service product called TM BioControl-1 were both registered in Canada in 1983. In 1983, the last outbreak of Douglas-fir tussock moth in B.C. terminated and neither of these products has been used operationally.B.C. Forest Service holds supplies of sufficient TM BioControl-1 to trat 8,000 ha and sufficient Virtuss to treat 1,400 ha. An outbreak of Douglas-fir tussock moth is predicted for 1991; these products will be applied operationally if the outbreak occurs.

The recommended dosage of virus for Douglas-fir tussock moth is 2.5×10^{11} PIB/ha in either an aqueous, molasses and Orzan tank mix or an emulsifiable oil tank mix applied at 9.4 L/ha. Non-replicated trials in 1982 indicated that a lower dosage. 8.3×10^{10} PIB/ha, gave acceptable results. The virus is known to spread and "seeding" it into the insect population using widely spaced swaths has been suggested.

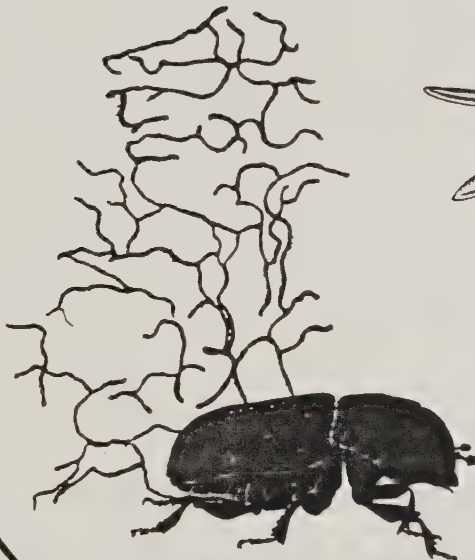
c) Redheaded Pine Sawfly

Lecontvirus, for control of redheaded pine sawfly, was registered in Canada in 1983. It is the only viral insecticide which is routinely used on an operational basis in Canada. Our principal client has been the Ontario Ministry of Natural Resources, although Quebec Department of Energy and Resources used Lecontvirus experimentally in the 1970's and have requested material for 1991. Dosage is 5×10^{9} PIB/ha applied in 10.0 L/ha from the air and 20.0 L/ha with ground spray equipment. The virus is produced inexpensively by treating heavily infested plantations and harvesting diseased and dead colonies of larvae. Between 1976 and 1990, 590 red pine and jack pine plantations with a total area of 4,855 ha have been treated.

d) European Pine Sawfly

A registration petition for Sertifervirus to control European pine sawfly was submitted in 1985 and is still being evaluated. The petition was based on the USDA Forest Service Neochek-S petition. The American product was registered by EPA in 1983 for use in the USA. European pine sawfly virus was extensively used on infested Scot's pine Christmas tree plantations in Ontario in the 1950's and 1960's with no thought given to registration and no records kept of areas treated. This insect is currently only a minor pest. Between 1976 and 1990 only 4 plantations, with a total area of 160 ha, have been treated. However, if a registration is obtained for Sertifervirus, greater use will be made of this product. Recommended dosage of 5×10^{9} PIB/ha is the same as that for Lecontvirus. Sertifervirus is also produced by spraying heavily infested plantations and harvesting diseased and dead colonies of larvae.

IDAHO FOREST INSECT and DISEASE REPORT



GYPSY MOTH ERADICATION PROGRAM

in

IDAHO

1989

Sandpoint and Coeur d'Alene

Bonner and Kootenai Counties

by

Robert (Bob) Tisdale, Gypsy Moth Program Coordinator

R. Ladd Livingston, Supervisor-Insect & Disease Section

STATE OF IDAHO

DEPARTMENT OF LANDS

COEUR D'ALENE

Report No. 90-4
October 1990

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

ABSTRACT

The Idaho Department of Lands with cooperation from the USDA Forest Service, Region 1, and the USDA-Animal and Plant Health Inspection Service implemented plans to eradicate the gypsy moth, Lymantria dispar L. from two infestation sites in north Idaho. Approximately 110 acres in Coeur d'Alene and 270 acres in Sandpoint were treated with Bacillus thuringiensis (Bt), a biological insecticide. Each site received three aerial applications of Bt at 7- to 10-day intervals.

A mass trapping program was implemented as a follow-up to the insecticide treatment using a trap density of 9 per acre. Approximately 150 acres in Coeur d'Alene and 675 acres in Sandpoint were trapped. A total of 28 moths were caught in Coeur d'Alene and 23 in Sandpoint. This represents a reduction from last year's catches of 67 percent and 93 percent, respectively. Two small infestations were delineated in each city.

An intensive egg mass survey was conducted covering 4 acres in Coeur d'Alene and 6 acres in Sandpoint. Two egg masses were found in Coeur d'Alene at one site. In Sandpoint five egg masses were found, four of which were at one site.

INTRODUCTION

The gypsy moth was first detected in Idaho in 1986 when one male moth was caught in a pheromone-baited survey trap at Sandpoint. In 1987, 22 males were caught at Sandpoint, 11 at Coeur d'Alene, and one each at Lewiston and Cascade.

An egg mass survey was performed in the Spring of 1988 with 1,440 properties being searched in Coeur d'Alene and 1,170 in Sandpoint. Forty-four egg masses were found in Sandpoint and three in Coeur d'Alene. A total of 4 properties in Coeur d'Alene and 21 in Sandpoint were found to have evidence of various gypsy moth lifestages.

In an effort to reduce the population as much as possible, a ground spray program was initiated in May of 1988. Orthene, an organic phosphorus insecticide, was used on ornamental trees, and the bacterium Bacillus thuringiensis, a biological insecticide, was applied to fruit trees. A total of 23 trees in Coeur d'Alene and 68 trees in Sandpoint were treated. Each tree was sprayed three times.

Summer pheromone trap and fall egg mass surveys revealed that the gypsy moth was still present in both towns. In Coeur d'Alene 87 male moths were caught and 2 egg masses located. In Sandpoint 334 male moths were caught and 32 egg masses located. A direct comparison of pheromone trap catches between 1987 and 1988 cannot be made as a grid system of trap placement covering all of the infested area was used for the first time in 1988.

In a fall evaluation of the gypsy moth situation, it was the consensus of the Idaho Department of Lands, the USDA Forest Service, the USDA-Animal and Plant Health Inspection Service, and the Idaho Department of Agriculture that the gypsy moth was established in Sandpoint and Coeur d'Alene and that an eradication effort should be initiated.

An environment assessment (Rivas 1989) was prepared covering several options; public meetings were held; news releases and general information was provided to newspapers and radio and television stations of the area; and general information covering the gypsy moth and announcements for the public meetings were hand-delivered or sent to all residents within the proposed treatment areas.

After reviewing the situation and receiving public comment, the Idaho Board of Land Commissioners on May 1, 1989, authorized implementation of plans to eradicate the gypsy moth from Idaho.

OBJECTIVES

1. To eradicate the gypsy moth from Idaho using the following procedures:

    a. To implement three aerial applications of the biological insecticide Bacillus thuringiensis (Bt) to infestation sites in Coeur d'Alene and Sandpoint. Bt works best on first through third instar larvae. Three applications of Bt are necessary due to the prolonged hatching period of gypsy moth and the short active life of the pesticide.

    b. To implement a mass trapping program as a follow-up to the insecticide treatment. Mass trapping is employed to further reduce and to locate any residual population not affected by the insecticide.

2. To conduct an intensive egg mass survey in areas where multiple moth catches occur. Results of egg mass surveys are used as gauges to measure the effectiveness of control programs and also as aids in planning future action.

PUBLIC INFORMATION

The information effort was to inform and educate the public about the pest, the need to control it, and the pesticide to be used. Special care was taken in selecting the pesticide due to concerns for the environmental and for human health when using an insecticide in an urban area. A total of four public meetings were held in Coeur-d'Alene and Sandpoint. Overall consensus was favorable for the spray project.

Numerous articles appeared in local newspapers throughout the time of the entire program. The content of the articles ranged from general information about the gypsy moth to announcing spray dates and times. Presentations were also given to the County Commissioners for both Kootenai and Bonner counties.

Fliers announcing the first aerial application of insecticide were distributed to residents within the project areas the evening prior to the first treatment (Appendix B and C). Local Boy Scout troops were contracted to distribute them.

A toxicology profile for the Bt pesticide used was sent with a cover letter explaining the project to all physicians in both Coeur d'Alene and Sandpoint so that they could be familiar with the product (Appendix D).

PROGRAM AREA

The aerially-applied pesticide treatment area for Coeur d'Alene was 110 acres (Figure 1) and for Sandpoint 270 acres (Figure 3). The treatment areas for both cities were determined from the previous year's moth catches and egg mass locations. A perimeter buffer area of one block was added to assure complete coverage.

The mass trapping area encompassed and extended beyond the spray area for both Coeur d'Alene (Figure 2) and Sandpoint (Figure 4). Kootenai, a suburb of Sandpoint and several other sites (Figures 2 & 4), were also mass trapped because of single moth catches in 1988. A total of 150 acres in Coeur d'Alene and 675 acres in Sandpoint were mass trapped.

Figure 1.

Coeur d'Alene spray area

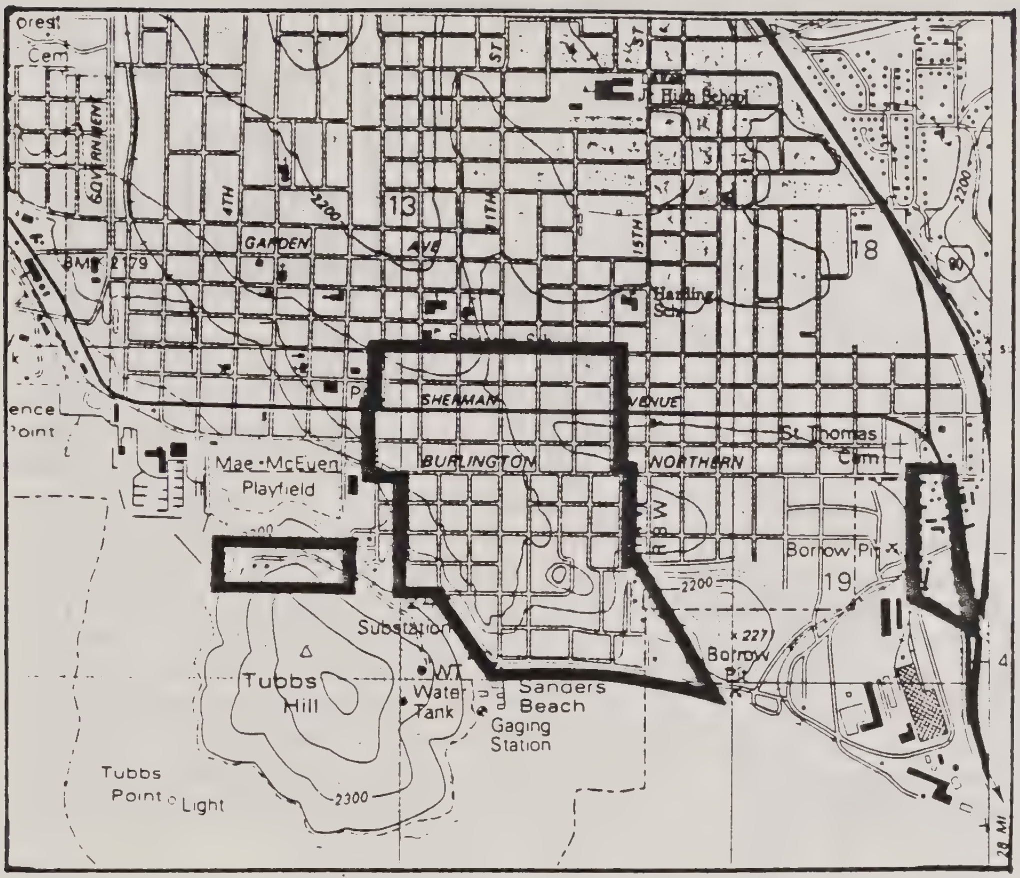


Figure 2.

Coeur d'Alene
mass trapping
areas

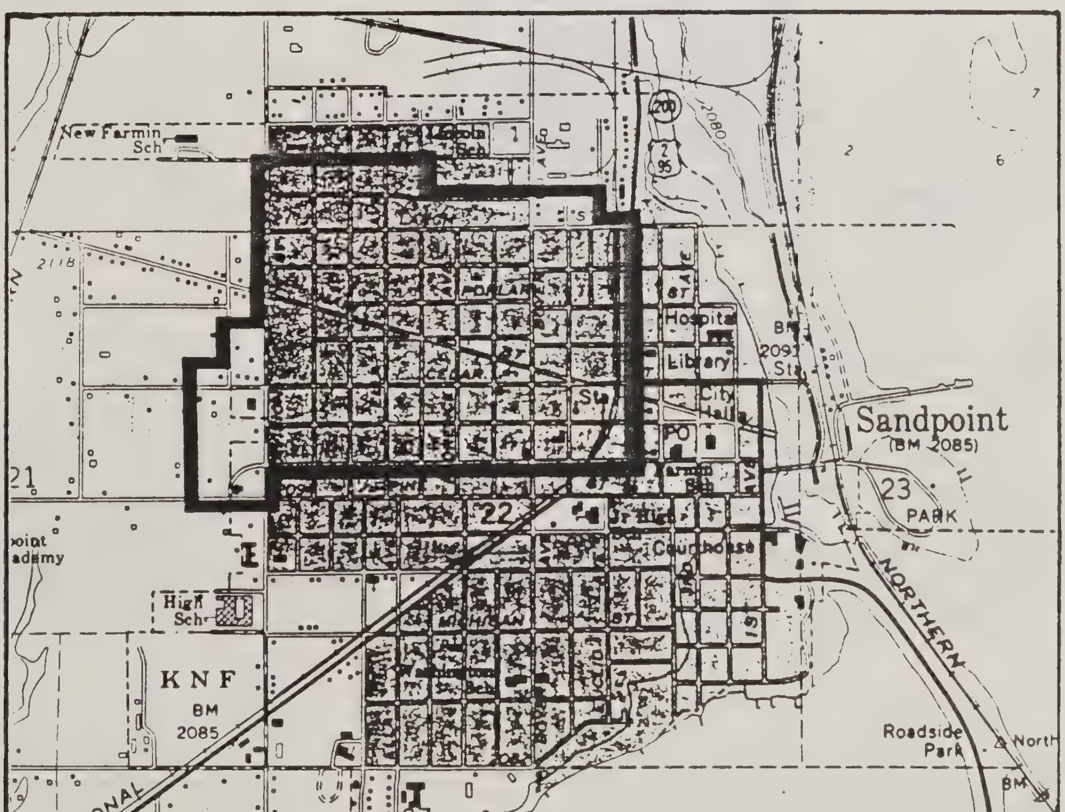
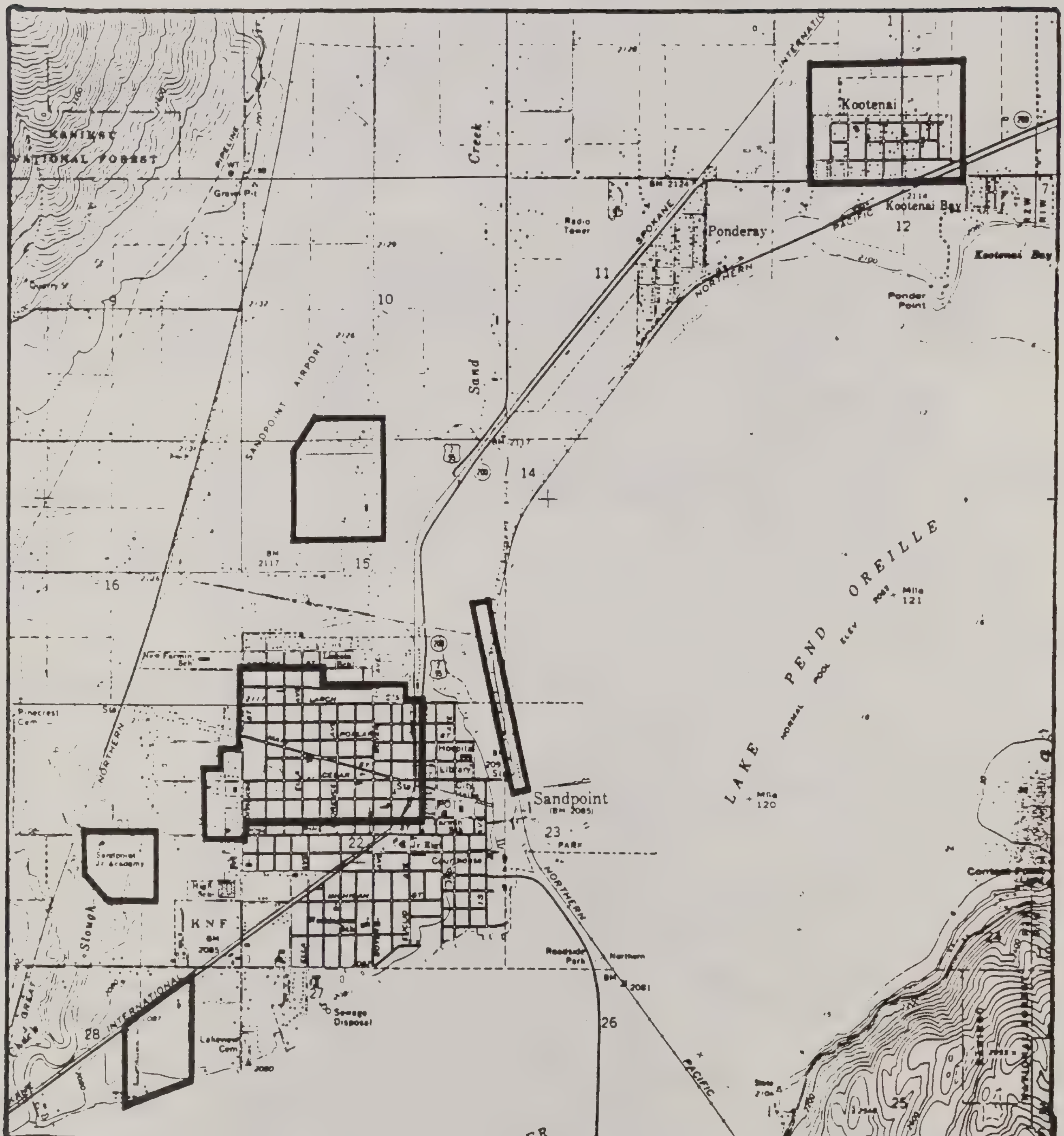


Figure 3.

Sandpoint
spray area.

Figure 4. Sandpoint mass trapping areas.



INSECTICIDE

Description

Dipel 8L, a biological pesticide produced by Abbott Laboratories was the pesticide of choice due to its narrow range of target insects and lack of general impact on the environment. It is an emulsifiable suspension of the bacterium Bacillus thuringiensis (Bt) insecticide designed for forestry applications. The Bt used in Dipel is a naturally occurring bacterium that is common in the environment. It is selective in that it is a natural pathogen affecting only the insects in the Order Lepidoptera (moths and butterflies). It has no known adverse effects on other arthropods or life forms such as man, pets, fish, or birds. Dipel 8L contains 64 BIUs of Bt per gallon. This formulation disperses readily into water and forms a free-flowing spray suitable for low volume aerial application. Dipel 8L is not classified as a hazardous material. The mode of action of Bt is as a stomach poison. It must be ingested by the larvae to be effective. Proteinaceous crystals formed during sporulation of the bacterium disrupt the stomach lining of larvae and causes them to cease feeding.

Mixing and Storage

All mixing took place at the MICA Fire Protection District office in Coeur d'Alene and at the Idaho Department of Lands compound in Sandpoint. Both locations had asphalt pavement which was a requirement of the Idaho Department of Environment for mixing sites. A gel-type absorbent was kept at the site in the event of a major spill.

The insecticide was mixed in the ratio of one gallon Dipel to two gallons water. Application rate was three quarts (96 oz.) mixture per acre which gave a final delivery of 16 BIUs Bt per acre. Plyac, a latex-based sticker/surfactant was added at the rate of 2 percent by volume of water. The amounts of each component for both spray areas are shown in Table 1. Mixing was done the evening before each spray. There was no concern about the possibility of the Dipel coming out of suspension because mixtures of Dipel will remain stable for periods of up to 144 hours under normal field conditions.

Table I. Amounts of each ingredient for both spray areas (gallons).

	Sandpoint: 270 acres	Coeur d'Alene: 110 acres
Water @ 2 qts/a	135	55
Plyac @2% by volume	2.7	1.1
Dipel 8L @ 1 qt/a	67.5	27.5
Total	205.5	83.6

The bulk Dipel was stored at the MICA Fire Protection District office in Coeur d'Alene. The insecticide was delivered in seven 55 gallon drums and placed under an outdoor shed. Several sheets of plywood were placed around the drums to protect them from direct sunlight. There was no concern about the Dipel freezing because temperatures were well above this at that time of year.

MONITORING EGG MASSES

In order to apply the insecticide at the stage when the larvae were most vulnerable, egg masses were monitored in the field to determine when egg hatch and larvae dispersal and feeding began. Our plan was to begin the treatment soon after the eggs were hatched and larvae dispersed. Twenty-four egg masses were monitored in Sandpoint. The egg masses found in Coeur d' Alene in 1988 had been removed; therefore, no observations were made there. Observations began April 24 and continued until treatment began. The egg masses were collected and destroyed when hatching began.

A gypsy moth phenology model, GMPHEN[1] was also used to predict timing of egg hatch. GMPHEN is a computer model that uses daily temperatures and published data to predict the timing of gypsy moth development. GMPHEN had been used in 1988 and was accurate to within one day in predicting commencement of egg hatch.

Six egg masses were collected and brought to the Insect and Disease Laboratory in Coeur d'Alene. Larvae from three of the egg masses were used for a spray bioassay. They were reared on foliage from

[1]GMPHEN: A gypsy moth phenology model; by Katharine A. Sheehan. USDA Forest Service, Portland, OR. Manuscript in review.

the two spray zones, and observations and mortality rates were recorded. The other three egg masses were used to determine percent of egg hatch.

SPRAY EQUIPMENT

The spray aircraft was a Hiller-Soloy 12E single-rotor, turbine-engine helicopter. The spray tank was fiberglass, with 140-gallon capacity, and externally mounted. The spray boom was 33 feet long and had three Beacomist Model 360A electronic rotary atomizer nozzles mounted on each side. The three nozzles on each side of the boom were spaced 21 inches apart with the inside nozzle 4.5 feet from the center of the aircraft. The contractor also furnished a 200-gallon fiberglass mix tank mounted on a one-ton flatbed truck. The mix tank was fitted with a recirculation pump which provided adequate agitation for mixing.

In order to gain authorization for low-level spray flights over the cities all aspects of FAA Agricultural Aircraft Operations Regulations 137.51 and 137.53 had to be complied with. Signs were posted on all major streets at the entrance to the spray areas on the day of each operation. Written approval was obtained from the mayors and city councils of Coeur d'Alene and Sandpoint. Notice of operation was given 48 hours in advance by radio, newspaper, and fliers. Flight plans were prepared and flight hazards and emergency landing sites were identified for each city. Pilot experience and aircraft maintinance requirements were also met.

CALIBRATION AND CHARACTERIZATION

Calibration was performed at the MICA office heliport in Coeur d'Alene. Water was used since its specific gravity was essentially the same as that of the final mixture (.97). System malfunctions and leaks were detected and corrected at this time.

The six Beacomist nozzles produced a 50-gallon delivery rate in 6.6 minutes at a boom pressure of 27 psi. This coincided with the predetermined figure of 10 acres per minute at 50 mph with an effective swath width of 100 feet. This gave the desired delivery rate of 96 ounces per acre.

Characterization was performed on the median strip at the Coeur d'Alene airport. Five cardlines, each with 20 cards at 10-foot intervals, were used. After the five trials, it was determined that drop density and volume median diameter (VMD) were within predetermined specifications of not less than 20 drops/cm^2 and 100-150 VMD, respectively. The predetermined altitude of 50 feet was increased to 60 feet in order to obtain a swath width of 100 feet.

SPRAY DEPOSIT ASSESSMENT

Spray deposit was assessed using Spraying Systems Company Teejet® water-sensitive cards. Five cardlines, for each spray, were placed within the treatment areas in Coeur d'Alene and Sandpoint. Each cardline consisted of 10 cards spaced 20 feet apart. The cards, inserted in plastic holders, were placed in the middle of streets or, if no canopy was present, on sidewalks. The cards were picked up immediately after the spray had settled in order to prevent damage to them from automobiles.

The cards were later analyzed for drop density and VMD. Drop density was determined using a plastic template. VMD was determined using the D-max method (Dumbauld and Rafferty 1977).

Spray behavior and deposit was modeled using the FSCBG model developed by the USDA Forest Service (Bjorklund and others 1988). Model runs were completed for both Coeur d'Alene and Sandpoint.

FLIGHT PATH FOLLOWING

A Pathlink™ Recorder Model PR2000 supplied by Pathcor Div. of Technology Projects Ltd., Tempe, Arizona, was mounted on board the spray aircraft. The Pathlink system provides a method for determining and documenting location based on latitude and longitude, and event status of any vehicle operated within a geographical area covered by an adequate LORAN-C signal. We attempted to record flight path and spray boom on\off information.

METEOROLOGICAL CONDITIONS

Spot weather forecasts were provided by the National Weather Service in Missoula, Montana. Weather data was collected at the spray site the morning before each treatment and submitted to the weather service via a Data General communications computer located at the MICA Fire Protection District office in Coeur d'Alene. The forecast was received by late afternoon the same day. Weather information was also obtained from the flight weather service at Spokane airport. Decisions on whether or not to commence treatment were based on information from these two sources.

There were eight criteria for terminating the spray operation (Rivas 1989). However because of the time of year and time of day when the operation was scheduled, we were only concerned with two of them, wind speed of greater than 8 mph and threat rain within six hours of application.

MARKING SPRAY BOUNDARIES AND SWATHS

Forty-inch yellow helium balloons were used to mark the spray area boundaries and swaths. Each balloon was attached to a 100-foot length of braided fishing line. One balloon was placed at each corner of the treatment areas to mark the boundaries. To mark the swaths, balloons were placed at 400-foot intervals on one side of the spray zone. The pilot was able to estimate each 100-foot swath width between the 400-foot markers.

Caution signs were placed at major intersections leading into the treatment areas. The signs were 18-inch by 28-inch orange construction paper with black lettering. These were attached to fold-out type highway markers provided by the Idaho Department of Transportation.

MASS TRAPPING

Mass trapping has been used in conjunction with aerial insecticide applications to eradicate isolated populations of gypsy moth. In addition to serving as a control method, mass trapping is also a very effective means of pinpointing any residual population not affected by the insecticide application.

A trap density of 9 per acre was used for residential areas. Trap placement location was determined with the aid of aerial photographs. The acreage of each city block was calculated, and the appropriate number of traps assigned to them. Trap locations for each block were specified by making marks on the photograph with a felt pen. The marks, representing trap locations, were spaced as evenly as possible. This procedure greatly aided trap personnel in placing traps.

A trap density of 6 per acre was used in wooded areas. Locations to be trapped were indicated on maps, and personnel used 85-foot strings to set up a grid within these areas.

Information for each trap was recorded on individual data cards (Appendix E). Information recorded included city-site, trap number, address, location diagram, date placed, service record, and date removed. The location diagram was drawn so that someone other than the trapper could find the trap if need be.

In addition to placing traps, personnel were responsible for promoting good public relations. This included informing property owners about gypsy moth and the mass trapping program. Personnel were instructed to spend considerable time in this effort. Property owners were asked for permission before traps were placed.

If no one was at home, a letter (Appendix F) was left instructing the owner to call the Department of Lands if they did not want traps on their property.

It was predicted that some traps could not be placed due to property owners refusal to give permission. Trap personnel were instructed to assign a trap card and number for these locations. It was decided that, if a very large gap in trap placement was created because of refusals, personnel would return at a later date and try to obtain permission.

The trapping program began June 12 with a training session in Sandpoint. Trap placement began June 13 and ended July 17 when all traps were in place. All traps were checked twice weekly from July 22 until September 8. When a moth was caught, the trap was removed, replaced with a new one, and brought to the lab for positive identification of the moth.

EGG MASS SURVEY

An intensive egg mass survey was conducted following the mass trapping program. An intensive egg mass survey is used for small populations when a walk-through survey would result in no egg masses being detected. Selection of areas to be surveyed were based on having greater than four positive catches within one city block.

BUDGET

This project was funded by the Idaho Department of Lands with cooperative cost share suppression funds being provided by the USDA Forest Service, Region 1, and the USDA-Animal and Plant Health Inspection Service. Cost per acre for the spray project was $123.87/acre and $67.78/acre for mass trapping. Table II shows a budget summary.

RESULTS

Egg Mass Monitoring

Hatching of egg masses took place over a nine-day period (Table III). The first observed hatch was on April 28 when four egg masses began to hatch. The last egg mass began to hatch on May 5. The greatest number of egg masses that began to hatch on a single day was nine and occurred on May 3. GMPHEN predicted that egg hatching would commence on May 2.

Table II. Budget summary.

ITEM	COST
Spray:	
Aircraft	$27,690.00
Plyac	525.00
Personnel	10,842.47
Travel and Per Diem	1,333.41
Supplies	1,460.45
Vehicles	881.41
Miscellaneous	1,245.12
Public Meetings	915.43
Environmental Assessment	2,178.89
Sub-Total	47,072.18
Trapping:	
Personnel	51,154.27
Travel and Per Diem	2,286.41
Supplies	1,120.88
Sub-Total	54,561.56
Egg Mass Survey:	
Personnel	2,129.23
Total	103,762.97

Table III. Hatching dates of egg masses.

Date	4/28	5/1	5/2	5/3	5/4	5/5
Number hatching	4	3	3	9	1	1

All egg masses were removed and destroyed when the first hatching began except for two of them. These were left to determine how long the larvae remain on the egg mass before they disperse. Both

of these egg masses began to hatch on May 3. The larvae remained clustered on the egg mass until May 7, a period of four days. Of the 24 egg masses monitored, all but three had hatching take place.

Of the six egg masses brought to the laboratory, all had egg hatching occur. When hatching had apparently ceased, three of the egg masses were placed in the freezer overnight. This facilitated counting the larvae to determine the percent of egg hatch. Percent of egg hatch ranged from 92 percent to 96 percent (Table IV). The other three egg masses, the larvae of which were used in the spray bioassay, appeared to have hatching rates similar to those described above.

Table IV. Summary of percent egg hatch data.

Egg mass	Total eggs	Number hatched	Percent hatched
1	643	598	93
2	436	403	92
3	505	485	96

Spray Bioassay

Treated foliage from the second and third spray was used for the bioassay. Of the 52 larvae fed foliage from Sandpoint, there were no survivors. Of the 38 larvae fed foliage from Coeur d'Alene, there were four that survived to the adult stage. Two of these had developmental rates about three weeks longer than larvae reared on untreated foliage.

Spray Operation

Based on timing of egg hatch, the first spray for Coeur d'Alene was scheduled for May 10 and for Sandpoint May 11. Due to rain and high winds, the first spray was delayed for two days. The second spray for Coeur d'Alene and Sandpoint was completed on May 21 and May 22, respectively. The third spray for Coeur d'Alene was completed on May 30 and for Sandpoint on June 2.

Spray Deposit Assessment

Results are provided in Table V. Droplet density ranged from 3.9 to 29.1 and VMD from 109.7 to 132.6 for Coeur d'Alene. For Sandpoint, droplet density ranged from 19.8 to 52.3 and VMD from 104.8 to 116.9. The results for Coeur d' Alene are based on only four of the cardlines. The fifth cardline was located along the south border of the area next to the lake and, as predicted by the FSCBG spray behavior model (Bjorklund and others 1988), no spray was deposited there due to the prevailing south winds.

Table V. Summary of spray deposit data.

Coeur d' Alene:		
Spray	Drop density #/cm	VMD
1	10.85	109.67
2	3.94	132.58
3	29.10	124.46
Sandpoint:		
1	19.76	116.89
2	32.24	104.77
3	52.25	109.10

Flight Path Monitoring

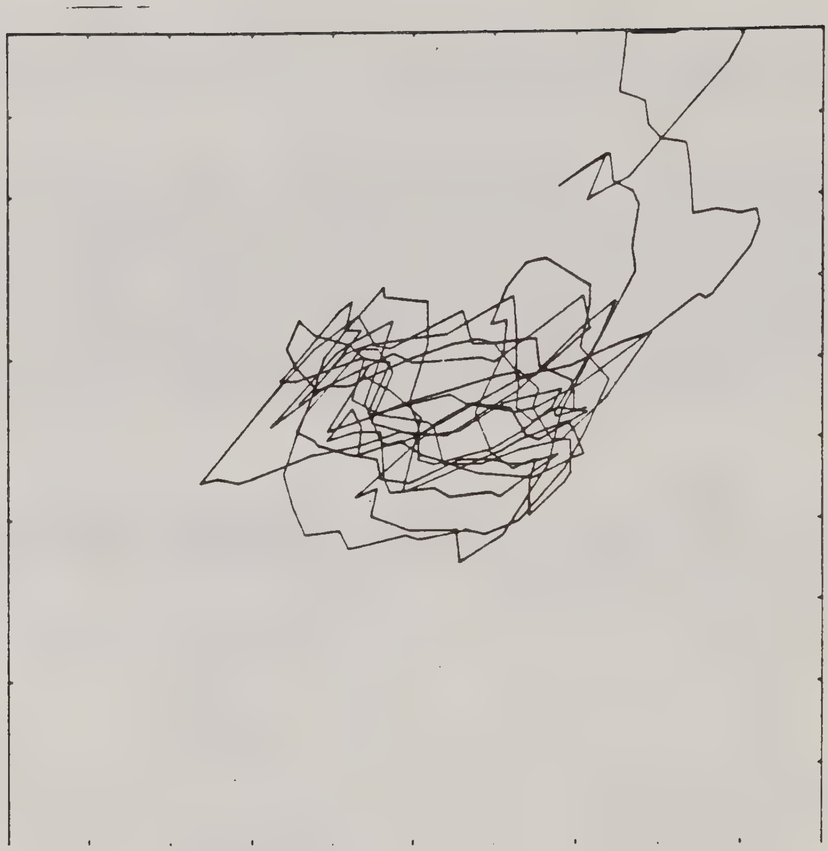
The flight path following system did not function as anticipated. Apparently the Hiller-Soloy 12E helicopter generated excessive static electricity that caused the figures produced by the system to show only jagged representations of the flight lines (Figure 5) that were not intelligible. Many efforts were tried using different Loran transmitters, improved grounding of the electronics units and different antennal positions, none of which improved the results.

Mass Trapping

A total of 1,343 traps were placed in Coeur d' Alene covering approximately 150 acres. There were no refusals from property owners to place the traps. A total of 5,907 traps were placed in Sandpoint covering approximately 655 acres. Due to property owner refusals, 117 traps were not placed. However, no large gaps were created in trap placement because of this.

Figure 5.

Unsuccessful plotting of spray block flight lines for Coeur d'Alene



A total of 28 male moths were caught within the mass trapping area in Coeur d'Alene. Two small pockets were delineated (Figure 6). One of the pockets had 18 catches and the other had four (Figure 7). The remaining six catches were scattered throughout the trapping area. Two of these catches were outside the spray area. Four other moths were caught in detection traps (Figure 6 and Appendix G).

In Sandpoint 23 male moths were caught within the mass trapping area. Two pockets were delineated (Figure 8). One of the pockets had 10 catches and the other had eight (Figure 9). The pocket with eight catches was located one block outside the spray area. The remaining five catches were isolated single catches. Four of these were within the spray area and the other was outside. Six other moths were caught in detection traps (Appendix G).

Egg Mass Survey

Based on positive pheromone trap catches, two locations in Coeur d' Alene and two in Sandpoint were surveyed. In Coeur d' Alene

two egg masses were found on a single property (Figure 7). In Sandpoint five egg masses were found (Figure 9). Four of these were found in one area; three on a single tree, while the fourth was detected on an adjacent property.

Figure 6. Mass trapping areas showing locations of moth catches and positive detection trap sites in Coeur d'Alene.

● = eradication moth catch sites, 9 traps per acre

■ ▲ = positive detection survey sites, 36 traps per square mile, all single moth catches

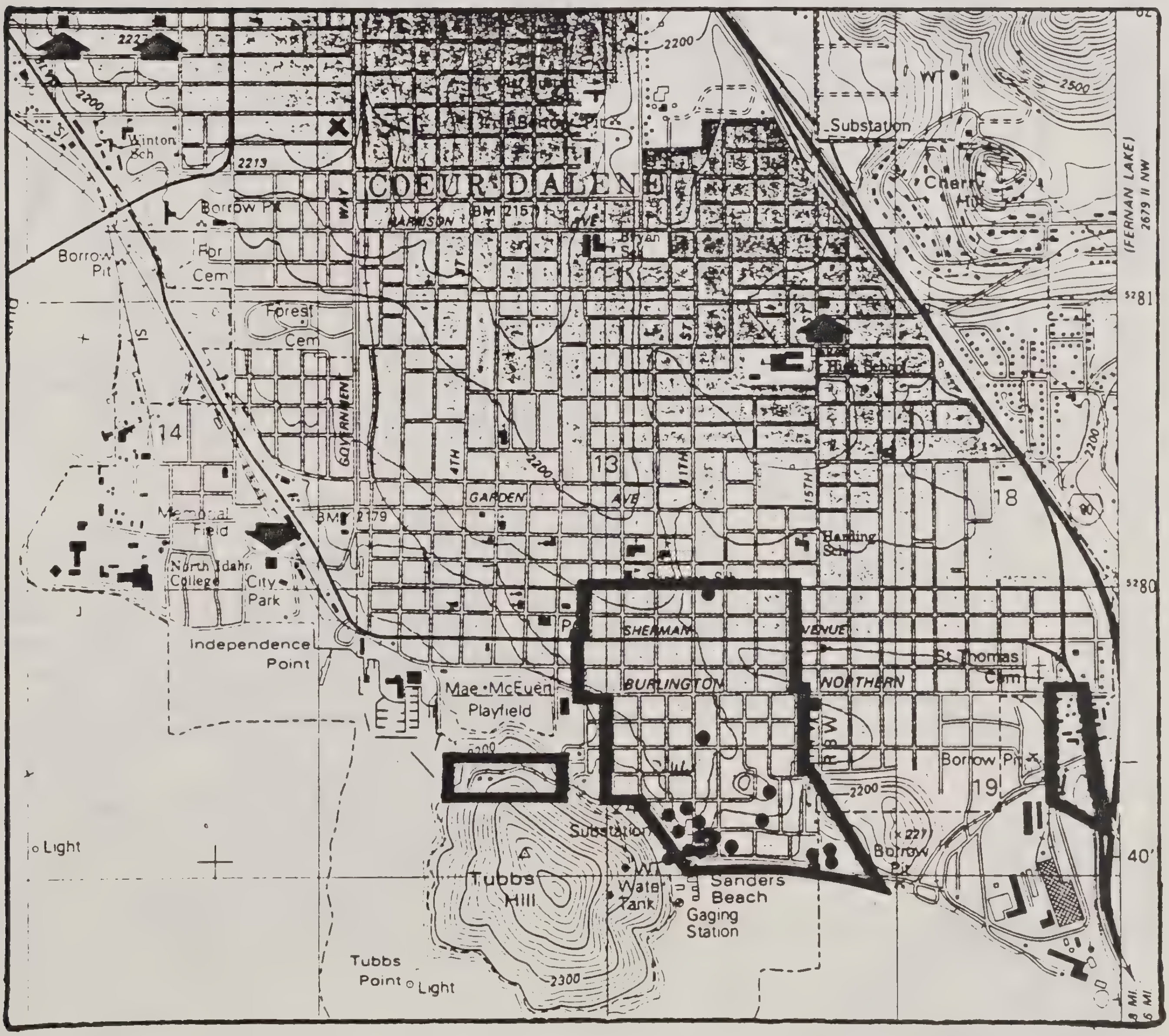


Figure 7. Detail of area of concentrated moth catches and egg masses found in Coeur d'Alene.

● n = site and number of moths caught

▲ n = site and number of egg masses found

Figure 8. Mass trapping areas showing locations of moth catches and positive detection trap sites in Sandpoint.

● = eradication moth catch sites, 9 traps per acre

■ = detection survey moth catches, 36 traps per square mile. Extra traps were placed at time of 1st catch.

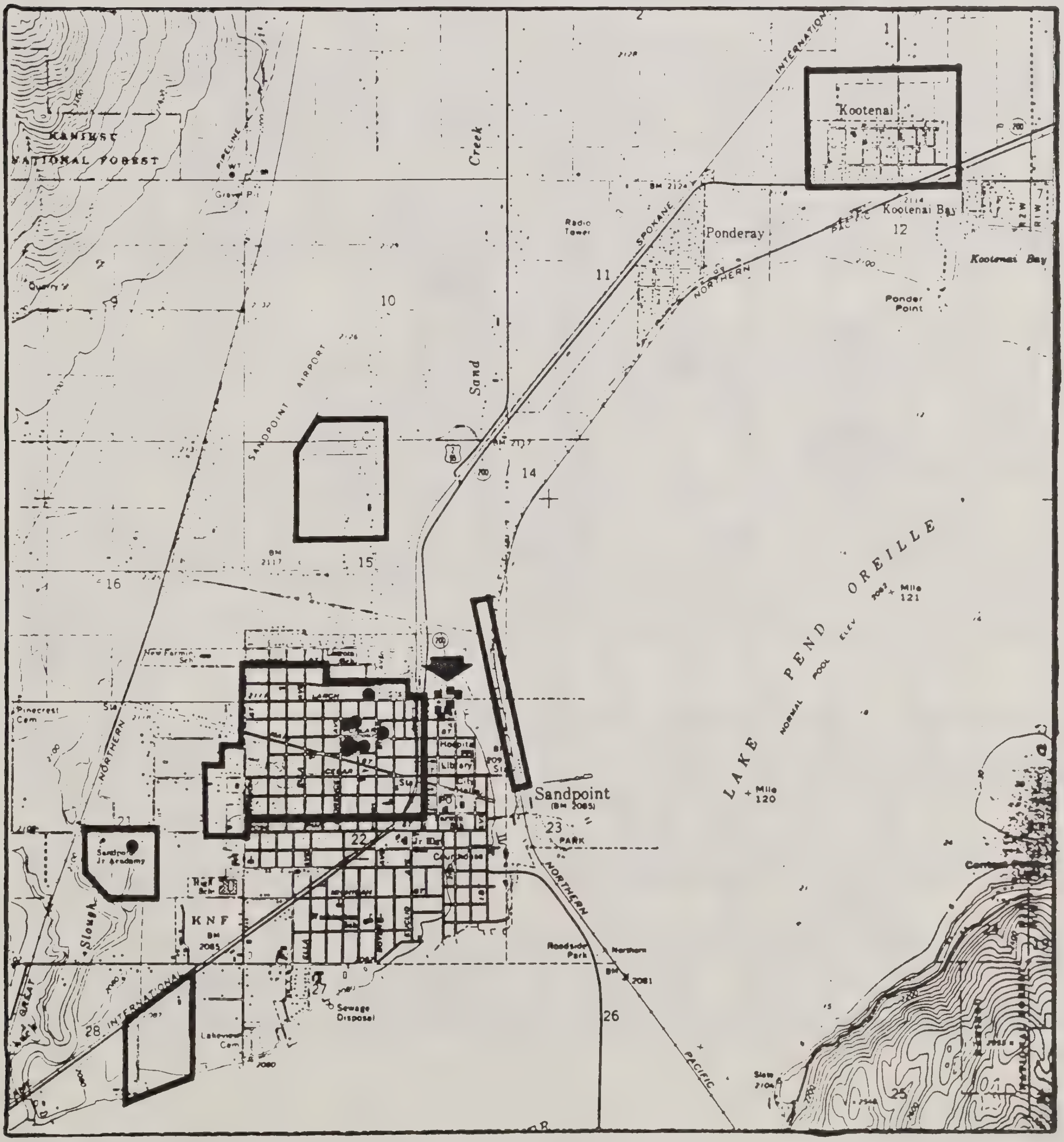
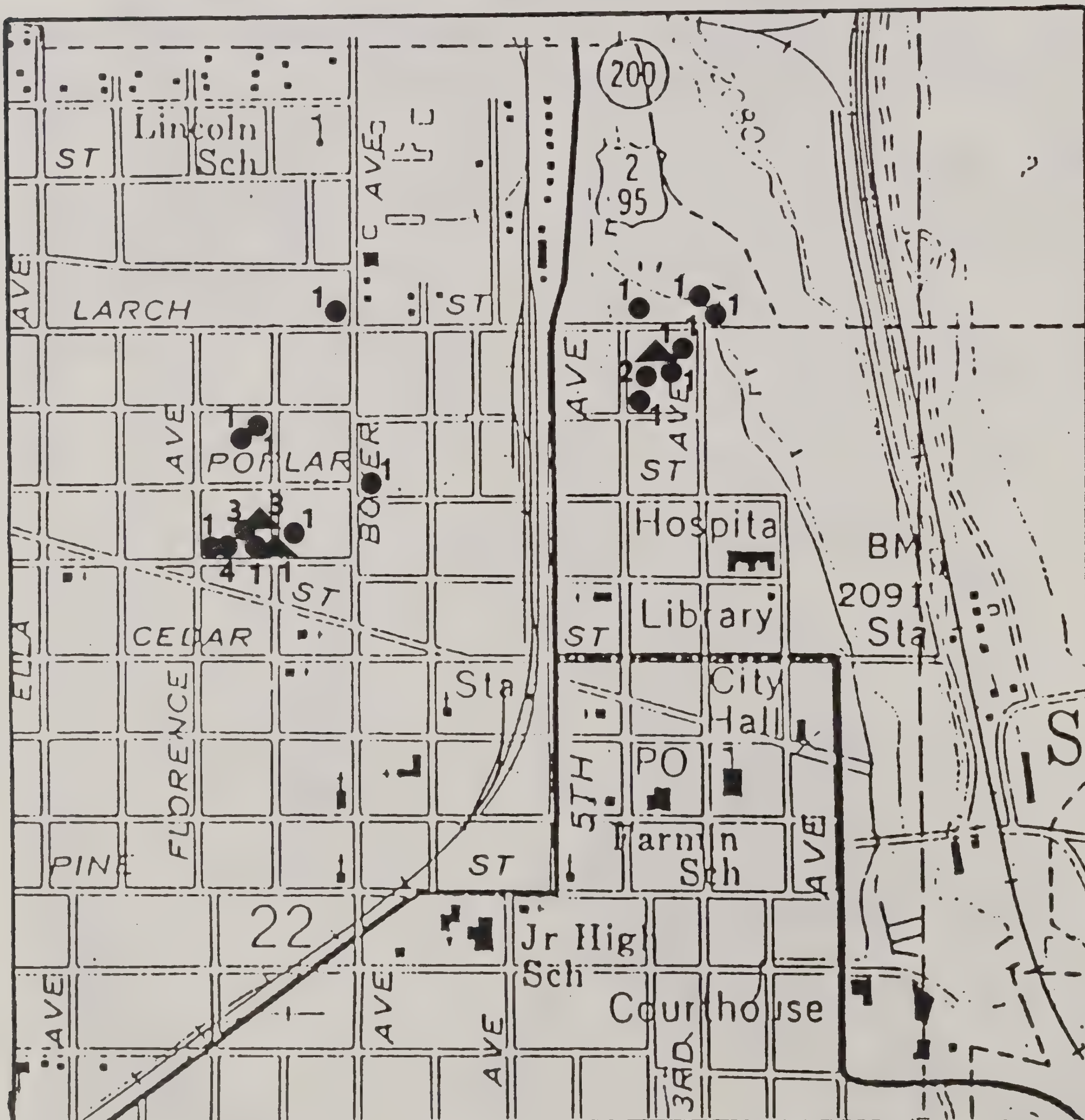


Figure 9. Detail of area of concentrated moth catches and egg masses found in Sandpoint.

●ⁿ = site and number of moths caught

▲ⁿ = site and number of egg masses found



DISCUSSION

In general the spray project and the mass trapping can be considered as successful. The pheromone trap counts in 1989 compared to 1988 dropped by 67 and 93 percent in Coeur d'Alene and Sandpoint, respectively. The egg masses were reduced in Sandpoint from 32 in 1988 to 5 in 1989. In Coeur d'Alene the numbers stayed the same with 2 in 1988 and 2 in 1989. However the infested area, as outlined by the survey traps, dropped from 110 acres to approximately 10 in Coeur d'Alene, and from 270 to 15 in Sandpoint.

The failure of the spray project to completely eradicate the gypsy moth population appears to be due to two factors. In Coeur d'Alene there was a continual south wind blowing from the lake that moved the spray inland before it was deposited. This had been predicted by the FSCBG model runs and the spray deposit cards showed this to be the case. The residual population, as determined by the pheromone traps and the location of the egg masses found, was confined to a narrow strip right along the lake shore. It appears that there was not adequate spray deposit to provide a lethal dose in that area.

In Sandpoint the residual population that was found within the boundaries of the spray block appeared to be associated entirely with one, very large, black walnut tree. Three of the four egg masses found at that site were on this tree and the fourth was only a very short distance away. We observed that all of the black walnut trees of the area were very slow in developing their foliage. The majority of the other host trees had nearly full foliage by the time of the first spray. When the foliage of the black walnuts did begin to develop, it appeared to grow so fast that there were new untreated leaves present within a very short time after each spray. This allowed a portion of the residual larval population to survive by feeding without contacting the pesticide.

The other Sandpoint population that was found outside of the spray area but within the mass-trapping zone may have resulted from an early instar female-caterpillar being blown by the wind the short distance outside of the original infestation area. It could have also resulted from movement of out door household articles. The low numbers of moths caught in the pheromone traps at that site would suggest that only one egg mass developed in the area.

The single moths that were caught some distance from the main population areas in both Coeur d'Alene and Sandpoint seem to have resulted from individuals that were either strong fliers or that got caught by the wind and were transported some distance from their point of origin. In all cases we have not caught any

additional moths when extra monitoring traps were placed around the sites where these single moths were caught.

While the mass trapping has obviously helped in the overall control effort, it apparently cannot be depended on to eradicate even low populations. This was demonstrated by our ability to find new egg masses within the trapping areas.

While we had hoped to eradicate the gypsy moth from Idaho with one year's efforts, it is apparent that it will take at least one more season.

REFERENCES

Bjorklund, J.R., C.R. Bowman and G.C. Dodd. 1988. User guide - Forest Service aerial spray computer model - FSCBG2. USDA Forest Service Forest Pest Management FPM 88-5

Dumbauld, R.K. and J.E. Rafferty. 1977. Field manual for characterizing spray from small aircraft. H.E. Cramer C., Inc. Salt Lake City, UT. Prepared for the USDA Forest Service, Equipment Development Center, Missoula, MT and the Methods Application Group, Davis, CA. 68p.

Rivas, A.M. 1989. Environmental assessment; gypsy moth eradication spray program. Bonner and Kootenai Counties, Idaho. Forest and Range Land Services, Ogden, UT. Prepared for the Idaho Department of Lands, Coeur d'Alene, Idaho. 36p.

1989 GYPSY MOTH CONTROL
PROJECT PERSONNEL

Project Director - R. Ladd Livingston
Project Coordinator - Bob Tisdale

Spray Program:

Ground crew	-	David Beckman Faith Bergem Tina Green Mike Brown
Flight following	-	Sandra Gast
Heliport managers	-	Steve Douglas Thomas Johnson (T.J.)
Pilot	-	James R. Pope
Crew chief	-	James D. Pope
Mixer	-	Greg Garris

Mass Trapping Program:

Sandpoint trap crew	-	Cheryl Aragon Mike Booth Mike D. Brown Mike L. Brown Sue Fogey John Krackenberg Alischia Matthews Jeannie Mikkelsen Jeff Ward
Coeur d'Alene trap crew	-	Faith Bergem Russ McCabe Janet Walker
Records clerk	-	Tina Green

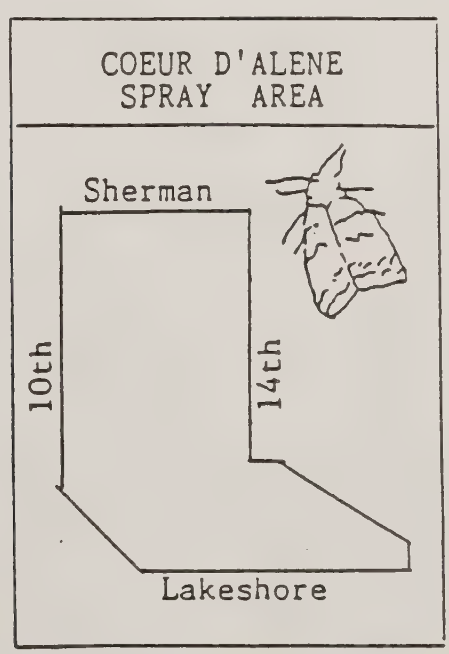
APPENDIX B

FLIER DISTRIBUTED TO RESIDENTS WITHIN COEUR d'ALENE SPRAY AREA

GYPSY MOTH SPRAY

The Idaho Department of Lands anticipates to begin aerial spraying for the gypsy moth on May 11, 1989. The actual spray date will depend on local weather conditions. Please listen to radio station KVNI for any changes. The spraying will start at approximately 5:00 a.m. and will end before 7:00 a.m. Two more sprays will be done at 7-10 day intervals following the first spray. The exact dates of the next sprays will be announced in the newspaper, on Radio station KVNI, and on Television station KXLY.

If you have any questions concerning the spraying please call the Department of Lands at 664-2171.

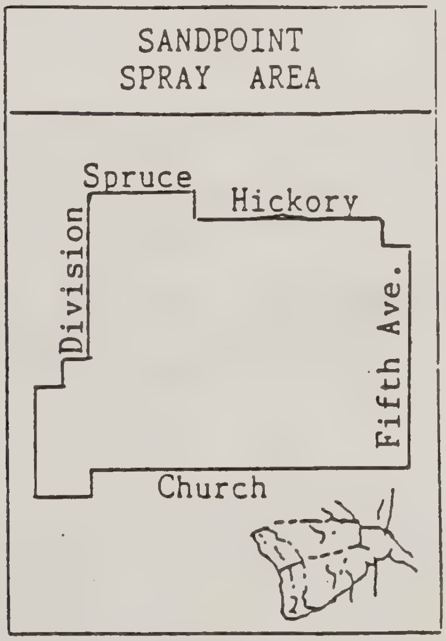


FLIER DISTRIBUTED TO RESIDENTS WITHIN SANDPOINT SPRAY AREA

GYPSY MOTH SPRAY

The Idaho Department of Lands anticipates to begin aerial spraying for the gypsy moth on May 12, 1989. The actual spray date will depend on local weather conditions. Please listen to radio station KSPT for any changes. The spraying will start at approximately 5:00 a.m. and will end before 7:00 a.m. Two more sprays will be done at 7-10 day intervals following the first spray. The exact dates of the next sprays will be announced in the newspaper, on Radio station KSPT, and on Television station KXLY.

If you have any questions concerning the spraying please call the Department of Lands at 664-2171 - Coeur d'Alene
263-5104 - Sandpoint



LETTER AND PESTICIDE TOXICOLOGY PROFILE SENT TO PHYSICIANS OF SANDPOINT AND COEUR D'ALENE

IDAHO DEPARTMENT OF LANDS
P.O. BOX 670, COEUR D'ALENE, IDAHO 83814

STANLEY F. HAMILTON
DIRECTOR

Date : April 28, 1989

Memorandum

To : Physicians of Sandpoint and Coeur d'Alene

From : R. Ladd Livingston, Ph. D.
Supervisor, Insect and Disease Section

Subject : Aerial Spray Project

During the first two weeks of May, 1989, the Idaho Department of Lands will begin aerially spraying portions of Sandpoint (see map) in an effort to eradicate the gypsy moth.

The biological pesticide to be used is Dipel (see attached toxicology profile). The active ingredient in Dipel is Bacillus thuringiensis (B.t.). It is a naturally occurring, soil inhabiting, ubiquitous bacterium. It is not toxic in any way to humans, animals, birds, or any insect other than caterpillars of moths and butterflies.

The spraying will begin at approximately 5:00 am and will end before 7:00 am. Two additional sprays will occur at 7-10 day intervals following the first spray. Exact dates for all sprays will be announced in the Sandpoint Daily Bee and on KSPT Radio.

We ask that you familiarize yourself with the aspects of this pesticide and help us in reassuring the general public of its safety. Your cooperation is greatly appreciated.

RLL/tg

LETTER AND PESTICIDE TOXICOLOGY PROFILE SENT TO PHYSICIANS OF SANDPOINT AND COEUR D'ALENE

dipel® TOXICOLOGY PROFILE

Bacillus Thuringiensis Insecticide

TOXICOLOGY

As evident from toxicology results, Dipel is one of the safest insecticides in use today. Its active ingredient is a bacterium, *Bacillus thuringiensis (B.t.)*, which occurs naturally in the environment. *B.t.* has a highly specific mode of action. It effectively controls caterpillar larvae; however, the HD-1 strain of *B.t.* used in the production of Dipel has shown no toxicity to mammals, fish or other wildlife at recommended field rates. This is supported by Abbott's extensive toxicologic evaluation of Dipel and extensive testing by independent scientists. Further, in over 10 years of commercial use, no reports of adverse effects to the environment have been documented. Unlike most chemical pesticides, Dipel is ideally suited for use in integrated pest management programs since the active ingredient does not interrupt activities of beneficial insects.

ORAL TOXICITY

No toxicity in mice, rats or dogs has been demonstrated with single dosages up to 10,000 mg/kg of body weight.

Thirteen-week dietary administration of technical material to rats at dosages of 8,400 mg/kg/day produced no toxic effects.

Two-year chronic dietary administration of technical material to rats at 8,400 mg/kg/day produced no tumorigenic or oncogenic effects.

INHALATION TOXICITY

No toxic effects were observed in rats when Dipel 4L was instilled directly into the lungs at rates up to 5 mg/kg of body weight. This translates to a value 10,000 times greater than a bystander could expect during spray programs. Humans exposed daily to *B.t.* spores for over 10 years have shown no adverse effects.

DERMAL TOXICITY

Mild, transient dermal irritation was seen, but no systemic toxicity was noted in rabbits when Dipel 4L was applied to abraded skin at 1 mg/kg/day for 21 days. In other studies, a single epidermal application of Dipel 4L at 7.2 g/kg was not toxic to rabbits.

TOXICOLOGY TO BEES

No toxicity to honeybees has been demonstrated during extensive laboratory and field studies with Dipel products at labeled rates.

TOXICITY TO BENEFICIAL INSECTS

No toxic effects to beneficial or predacious arthropods have been observed at labeled rates of Dipel. These results are based on laboratory and field studies performed on over 200 species of beneficial insects/spiders in the orders: Hymenoptera, Diptera, Neuroptera, Orthoptera, Araneae, Coleoptera and Hemiptera. Due to its safety to beneficials and unique mode of action, Dipel is an ideal component of integrated pest management programs.

EYE IRRITATION

No corneal opacity was observed in rabbits treated with 0.1 ml of Dipel 4L. Only mild, transient irritation was noted in this study, and in other tests with wettable powder formulations.

SENSITIZATION

No evidence of sensitization was noted in guinea pigs given repeated subcutaneous injections of *B.t.* technical material.

I.V. INJECTION

A single I.V. dose of 10^8 *B.t.* spores was not toxic to young growing rats. There was no evidence of sporulation of *B.t.* within the visceral tissues over the course of a 112-day experiment.

TOXICITY TO FISH

No adverse effects were shown in rainbow trout and bluegills exposed to *B.t.* technical material for 96 hours at concentrations of 560 and 1,000 ppm.

A small marine fish, *Anguilla anguilla*, was not adversely affected by exposure to 1,000-2,000 times the level of *B.t.* expected during spray programs.

Field observations, one month after aerial application of Dipel, revealed no effects on populations of brook trout, common white suckers and small-mouth bass.

TOXICITY TO ZOOPLANKTON

Aerial spraying at labeled rate of Dipel 4L, had no effects on populations of Cladocera, Copepoda and Rotifera species.

TOXICITY TO BIRDS

LD_{50} — Bobwhite Quail — greater than 10 grams *B.t.*/kg body weight; autopsy of the birds revealed no pathology attributable to *B.t.* LD_{50} — Mallard — greater than 2000 grams *B.t.*/kg. Field observations of 74 bird species revealed no population fluctuations after aerial application of Dipel.

RESIDUES

Since Dipel products have not been shown to be toxic to nontarget organisms, spray drift and residues do not present a health hazard.

TOLERANCE

Dipel has been granted exemption from the requirement of tolerance on all registered crops in Canada and the United States. The wettable powder formulation may be applied to certain raw agricultural commodities after harvest.

VIRAL ENHANCEMENT

The susceptibility of cell cultures to viral infection was not enhanced after Dipel 4L exposure.

APPENDIX E

TRAP DATA CARD

TRAP NO. ____________ – ____________
(City/Site No.) (Trap No.)

COUNTY ______________________

AREA ______________________
(N, SW, SE)

SURVEYOR ________
(Initials)

CITY/SITE ______________________

ADDRESS ____

DATE TRAPS SERVICED	TRAP CATCH (Put date trap set here)	INSPECTOR

PROPERTY DIAGRAM

N
W E
S

(If trap is relocated, indicate location of new trap site.)

IDAHO GYPSY MOTH SURVEY
TRAP CARD

LETTER ASKING PERMISSION TO PLACE TRAP

Date ____________________

TO: Occupant(s) of ________________________________

FROM: R. Ladd Livingston, Supervisor
Insect & Disease Section - 664-2171

SUBJECT: GYPSY MOTH TRAPPING PROGRAM

Each summer the Idaho Department of Lands conducts a trapping program to search for new introductions into our state of an insect called the "gypsy moth." This is accomplished by placing a small, orange or green gypsy moth trap in trees or on fence posts at strategic sites. The trap contains a lure which attracts male gypsy moths to it. The moths are then caught in the trap. There are no harmful chemicals in the trap.

Our survey technician (trapper) for your area has attempted to find someone home at your residence to request your permission to place a trap on your property. It is important that all traps be "in place" before the end of July. Therefore, the survey technician, in an effort to get the traps placed in time, has put one or more traps on you property at the following site(s):

____

____

If you would prefer not to have a trap on your property, please contact,

____
(Name) (Phone)

and the trap will be removed.

A survey technician will check your trap(s) twice during the summer, and remove the traps on the third visit at the end of September or early in October.

Attached is some literature about the gypsy moth and the trap.

Thank you very kindly for your assistance.

RLL/tg

LISTING OF MOTH CATCHES and EGG MASSES FOUND, BY ADDRESS

SANDPOINT, BONNER CO.

SURVEY TYPE*	TRAP NUMBER	ADD\DESC.	TRAP PERIOD #1 DATE	TRAP PERIOD #1 NO.MTHS	TRAP PERIOD #2 DATE	TRAP PERIOD #2 NO.MTHS	TRAP PERIOD #3 DATE	TRAP PERIOD #3 NO.MTHS	TOTAL MOTHS	EGG MASSES
d	20	PINECREST LOOP	9/25/89	1					1	
d	22	UPLAND DR	9/25/89	1					1	
d	23	UPLAND DR	9/25/89	1					1	
d	25	UPLAND DR	8/21/89	1					1	
d	48	MT VIEW RD	9/25/89	1					1	
d	58	WOODLAND DR	9/25/89	1					1	
**		321 LARCH							0	1
e	1608	805 BOYER	8/18/89	1					1	
e	2179	404 LARCH	8/16/89	1					1	
e	2187	302 LARCH	8/18/89	1					1	
e	2188	302 LARCH	8/16/89	1					1	
e	2204	712 FOURTH	8/16/89	1					1	
e	2207	716 FOURTH	8/16/89	1	8/21/89	1			2	
e	2212	719 THIRD	8/16/89	1					1	
e	2214	719 THIRD	8/16/89	1					1	
e	2308	602 BOYER	9/29/89	1					1	
e	2745	812 ALDER	8/08/89	1	8/15/89	3			4	3
e	2746	814 ALDER	8/08/89	1					1	
e	2747	808 ALDER	8/07/89	1	8/15/89	1	8/21/89	1	3	
e	2748	804 ALDER	8/22/89	1					1	1
e	2751	813 POPLAR	8/08/89	1					1	
e	2753	813 POPLAR	8/10/89	1					1	
e	2774	504 FOREST	8/07/89	1					1	
e	5269	2016 BROWNING	10/03/89	1					1	
		TOTALS: No traps: 23	No.Moths:	23		5		1	29	5

* "e" = eradication trap; "d" = detection trap

** egg mass only

LISTING OF MOTH CATCHES and EGG MASS FOUND, BY ADDRESS

COEUR D'ALENE, KOOTENAI CO.

SURVEY TYPE*	TRAP NUMBER	ADD\DESC.	TRAP PERIOD #1 DATE	TRAP PERIOD #1 NO.MTHS	TRAP PERIOD #2 DATE	TRAP PERIOD #2 NO.MTHS	TRAP PERIOD #3 DATE	TRAP PERIOD #3 NO.MTHS	TOTAL MOTHS	EGG MASSES
d	17	CITY PARK-PUBLIC RESTROOM	9/25/89	1					1	
d	71	1038 15TH	8/11/89	1					1	
d	134	MEDINA AVE	9/25/89	1					1	
d	135	1001 EMMA	9/25/89	1					1	
e	3	1109 CDA	8/22/89	1					1	
e	212	301 S. 15TH	8/23/89	1					1	
e	441	1307 ASH	8/23/89	1					1	
e	455	609 DOLLAR	8/15/89	1					1	
e	502	1415 E. LAKESHORE	8/15/89	1					1	
e	544	1215 E. LAKESHORE	8/11/89	1					1	
e	562	S. SIDE OF E. LAKESHORE DR.	9/18/89	1					1	
e	569	1501 E. LAKESHORE DR.	8/15/89	1					1	
e	576	1501 E. LAKESHORE DR.	8/29/89	1					1	
e	929	420 S. 11TH	8/10/89	1					1	
e	1257	815 S. 11TH	8/11/89	1					1	
e	1262	801 S. 11TH	8/17/89	1					1	
e	1266	777 S. 11TH	8/18/89	1					1	
e	1269	771 S. 11TH	8/15/89	1					1	
e	1277	720 S. 11TH	8/15/89	1					1	
e	1292	ASH ALLEY BET 11TH & 12TH	8/11/89	1					1	
e	1294	806 S. 11TH	8/07/89	1					1	
e	1296	1101 E. LAKESHORE	8/10/89	1	8/14/89	1	8/18/89	1	3	2
e	1297	1101 E. LAKESHORE	8/07/89	1	8/08/89	1	8/14/89	1	3	
e	1299	1103 E. LAKESHORE	8/14/89	1					1	
e	1300	1103 E. LAKESHORE	8/30/89	1					1	
e	1304	811 S. 12TH	8/11/89	1	8/14/89	1			2	
e	1320	1010 S. 10TH	8/22/89	1					1	
		TOTALS: No traps: 27	No.Moths:	27		3		2	32	2

* "e" = eradication trap; "d" = detection trap

AERIAL APPLICATION OF NUCLEAR POLYHEDROSIS VIRUS AGAINST DOUGLAS-FIR TUSSOCK MOTH, *ORGYIA PSEUDOTSUGATA* (McDUNNOUGH) (LEPIDOPTERA: LYMANTRIIDAE): I. IMPACT IN THE YEAR OF APPLICATION

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Abstract

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Four 10-ha plots located in Kamloops Forest District, British Columbia, containing Douglas-fir trees infested with Douglas-fir tussock moth were aerially sprayed with nuclear polyhedrosis virus (Virtuss) in 1982 when most larvae were in the first instar. A dosage of 2.5×10^{11} polyhedral inclusion bodies (PIB) per hectare was applied in an emulsifiable oil tank mix to one plot and the same dosage in an aqueous tank mix containing molasses was applied to a second plot. The remaining two plots were treated with dosages of 8.3×10^{10} and 1.6×10^{10} PIB per hectare, respectively, in the oil mix. The treatments were applied with a fixed-wing aircraft fitted with boom and nozzle equipment and calibrated to deliver 9.4 L/ha. A further four plots were selected as checks.

Population reduction at 6 weeks post-spray (calculated using a modified Abbott's formula) was 65% in the plot receiving the lowest dosage and from 87 to 95% in the remaining three plots. Incidence of virus infection, determined microscopically, peaked at 5–6 weeks post-spray with 85–100% of the larvae scored as positive. Levels of naturally occurring virus remained low in the check plots. Adult emergence from the pupae collected in the treated plots ranged from 4 to 19% and from 28 to 43% in the check plots. Reduction in egg-mass density attributed to the treatments was 97% in one plot, 99% in two others, and not determined for the fourth.

A virus dosage of 8.3×10^{10} PIB per hectare, which is one-third of the previously recommended dosage, is adequate, and either tank mix is acceptable.

Résumé

En 1982, quatre placettes de 10 ha situées dans le district forestier de Kamloops, en Colombie-Britannique, qui renfermaient des douglas taxifoliés infestés par la chenille à houppes du douglas ont été traitées par des épandages aériens de diverses préparations du virus de la polyédrose nucléaire (Virtuss) au moment où la plupart des larves se trouvaient au premier stade. Une première placette a reçu une dose de $2,5 \times 10^{11}$ corps d'inclusion polyédriques (CIP) par hectare sous forme d'une préparation huileuse émulsionnable, et une autre, la même dose, mais dans une préparation aqueuse contenant des mélasses. Les deux autres placettes ont reçu une préparation huileuse contenant $8,3 \times 10^{10}$ CIP/ha dans un cas et $1,6 \times 10^{10}$ CIP/ha dans l'autre. Les traitements ont été réalisés à l'aide d'un avion muni d'une rampe de pulvérisation étalonnée pour un débit de 9,4 L/ha. Quatre autres placettes ont été utilisées comme témoins.

Six semaines après les arrosages, la réduction de la population due au traitement (calculée suivant la formule modifiée d'Abbott) s'élevait à 65 % dans la placette ayant reçu la dose la plus faible et elle variait entre 87 et 95 % dans les trois autres placettes. L'infection virale, déterminée au microscope, a été maximale vers la 5e ou 6e semaine après l'arrosage, de 85–100 % des larves étant alors infectées. Le niveau d'infection naturelle dans les placettes témoins est demeuré faible. On a observé des taux d'émergence d'adultes variant entre 4 et 19 % chez les chrysalides récoltées dans les placettes traitées et entre 28 et 43 % chez celles des placettes témoins. La réduction de la densité

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des masses d'oeufs attribuable au traitement a été de 97 % dans une placette et de 99 % dans deux autres; elle n'a pas été déterminée dans la quatrième.

On estime qu'une dose de 8,3 × 10^{10} CIP/ha, soit le tiers de la dose déjà recommandée, est suffisante et que les deux préparations sont acceptables.

Introduction

The bionomics of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), in British Columbia and the western United States (U.S.A.) have been reviewed by Wickman and Beckwith (1978) and Shepherd *et al.* (1984*b*). Naturally occurring nuclear polyhedrosis virus (NPV) epizootics usually terminate Douglas-fir tussock moth outbreaks (Dahlsten and Thomas 1969; Mason and Luck 1978), but not before trees are severely defoliated or killed (Wickman 1978).

Dissemination of virus as a biocontrol agent was considered as early as 1962 in British Columbia (Morris 1963), but it was not until 1975 that large-scale aerial spray experiments were conducted in collaboration with U.S.D.A. Forest Service personnel in British Columbia (Stelzer *et al.* 1977; Shepherd 1980; Cunningham and Shepherd 1984). Two NPV morphotypes were tested: a unicapsid type with virus particles embedded singly in inclusion bodies and a multicapsid type with bundles of virus particles occluded. Subsequently, the multicapsid type was registered by the Environmental Protection Agency in the U.S.A. in 1976. The same virus, propagated in whitemarked tussock moth, *Orgyia leucostigma* (J.E. Smith), was granted a temporary registration in Canada in 1983 under the name Virtuss. This product contains lyophilized, virus-infected larvae ground to a fine powder.

Virtuss was applied both from the air and the ground in 1981 at the early phase of a Douglas-fir tussock moth outbreak in south-central British Columbia before the occurrence of a natural virus epizootic. From the air, a dosage of 2.2 × 10^{11} polyhedral inclusion bodies (PIB) per hectare in 11.3 L/ha was applied; from the ground, a dosage of 2.4 × 10^{10} PIB in a volume of 4.5 L was applied to each tree. All treatments prevented outbreaks (Shepherd *et al.* 1984*b*). Aqueous tank mixes with the addition of 25% (v/v) molasses were used in 1981; this mix has been widely used in previous tests in both Canada and the U.S.A. (Cunningham 1982). However, with the low relative humidity in the interior of British Columbia, spray deposits have often been poor.

In 1982, the second year of the Douglas-fir tussock moth outbreak at another location, Virtuss was again applied from the air, using two different tank mixes. In the water mix, the full dosage (2.5 × 10^{11} PIB per hectare) of the virus was used; in the oil mix, the virus was applied at the full dosage, as well as at two reduced dosages. The aim of these trials was 2-fold: (*a*) to compare an emulsifiable oil tank mix with an aqueous tank mix; and (*b*) to test reduced dosages of virus in the oil tank mix in an effort to reduce treatment costs. The impact of these treatments in the year of application, assessed by several different methods, is described.

Materials and Methods

Experimental plots. Four 10-ha plots containing Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissner) Franco, and a few scattered ponderosa pine, *Pinus ponderosa* Lawson, were selected for treatment near Veasy Lake, about 15 km northwest of Cache Creek, B.C., at elevations ranging from 700 to 900 m in the Kamloops Forest District. Four check plots (no treatment) were established in the same area (Fig. 1). Treatment plots were separated by a minimum buffer zone of 300 m and check plots were 300 m to 1 km away from the treated plots.

Treated plots were numbered T1, T2, T3, and T4 and matched to untreated check plots which had comparable insect population densities. Plot C4 was selected 3 days after the spray application because the pre-spray counts revealed that C1, C2, and C3 had much

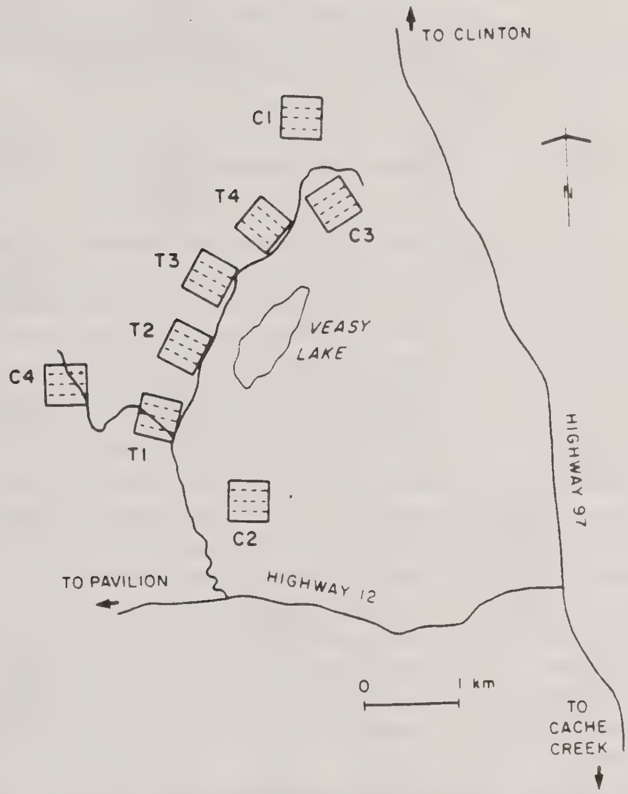

FIG. 1. Location of study plots for the experimental application of Virtuss on Douglas-fir tussock moth infested stands near Veasy Lake, Kamloops Forest District, B.C., 1982. Plots T1–T4 were treated and matching check plots were designated C1–C4. Broken lines through plots indicate lines of sample trees; spray aircraft flew at right angles to these lines.

higher population densities than spray plot T4 and a search was made for a plot with a comparable insect population density.

Spray application and monitoring deposit. Three dosages of Virtuss, 1.6×10^{10}, 8.3×10^{10}, and 2.5×10^{11} PIB per hectare, were tested in an emulsifiable oil carrier. The carrier was supplied by Abbott Laboratories and is the vehicle used to formulate their *Bacillus thuringiensis* Berliner variety *kurstaki* isolate HD-1 product called Dipel 88®. Virtuss was suspended in water and emulsifiable oil was added until the final ratio was one part of oil to three parts of water. A fourth plot was treated with 2.5×10^{11} PIB per hectare in an aqueous tank mix containing one part of animal-feed grade molasses to three parts of water. Rhodamine B dye at 0.04% was added to all tank mixes to monitor spray deposit.

Treatments were assigned randomly to the blocks. Timing of the spray application was determined by monitoring 50 Douglas-fir tussock moth egg masses per plot daily for larval hatch and dispersal. The spray was applied 1 week after 90% of the larvae had dispersed from these egg masses; the larvae were mainly in the first instar although a few second-instar larvae were present. A Cessna AgWagon was calibrated to deliver 9.4 L/ha through 42 Tee-Jets with 8005 nozzles mounted on the boom. Flight speed was 180 km/h at a height of 15 m above the tallest trees and the swath width was 30 m. Spraying was conducted at dawn when wind speed was about 2 km/h. The three treatments of Virtuss in emulsifiable oil were applied on 16 June, and the water and molasses tank mix was

applied on 17 June. Relative humidity on the ground was measured with a sling psychrometer. A rain gauge was used to measure precipitation for 1 week after application at the sites.

Spray deposit was monitored on Kromekote® cards held in wire holders about 50 cm above ground level placed about 10 m apart in openings in the forest canopy. Two lines of cards at right angles to the flight path were set 30 m from both ends of each treated plot. All cards were collected about 1 h after spraying and later analyzed for droplet density.

Egg-mass, larval, and pupal surveys. Fifteen Douglas-fir trees were selected as sample trees in each of three lines per plot giving a total of 45 sample trees per plot. There was about 110 m between lines and about 15 m between sample trees. None of the sample trees was closer than 50 m to a plot boundary. Sample trees were about 12 m tall and had ample foliage for weekly branch sampling. Egg-mass surveys (Shepherd *et al.* 1984*a*) were conducted in each plot in early spring, before eclosion and virus treatment, and again in late fall after oviposition was completed. The mean number of Douglas-fir tussock moth egg masses on three lower whole branches was recorded for each of the 45 sample trees. Pre-spray larval counts were made from two, 45-cm branch tips cut from the mid-crown of each sample tree in each plot: hence, counts were made from 90 branch samples per plot. Counts were made at weekly intervals until 6 weeks after spraying when pupation commenced. For each branch, foliated length, average foliated width, and number of live and dead larvae were recorded. The foliated area was calculated for each branch; the density of larvae for that area was converted to number of larvae per square metre and used to calculate standard deviation and standard errors. Sampling crews and equipment were assigned to either treated or check plots for the duration of the experiment to avoid contamination of the check plots with virus. Population reduction due to treatment was calculated using a modified Abbott's formula (Abbott 1925) described by Fleming and Retnakaran (1985). These calculations used mean numbers of live Douglas-fir tussock moth larvae derived by dividing the total number of larvae counted from the branch samples by the total foliated area (in square metres) of these branches. Approximately 1 week after pupation was first observed, cocoons were collected from all plots and reared to determine adult emergence and sex ratio.

Virus impact assessment. This was done by rearing larvae collected before the spray and by microscopic examination of larvae collected after the spray. Larvae, collected from the pre-spray population samples, were placed individually on artificial diet and reared until death or adult emergence. Dead larvae and pupae were examined microscopically to determine the cause of death. It was planned to collect 100–200 larvae per treated plot at weekly intervals commencing 2 weeks after spraying. However, after week 4, sample size dropped to as low as 60 in some treated plots due to virus-caused mortality and it was difficult to find living larvae; in T4 at week 7 only 20 were collected after intensive searching. The larvae were smeared on slides and examined microscopically for NPV. Larvae from check plots were examined for NPV 3, 5, 6, and 7 weeks after spraying.

Defoliation surveys. Defoliation due to Douglas-fir tussock moth larvae could not be estimated accurately because a low to moderate population of western spruce budworm, *Choristoneura occidentalis* Freeman, was also present in the plots.

Results

Spray deposit and meteorological conditions. At the time of spraying, wind speed was about 2 km/h, temperatures ranged from 11.5 to 21°C, and relative humidity from 46 to 63% (Table 1). Spray deposit was observed on all the cards. Best coverage was obtained with the aqueous tank mix containing molasses, with 27.3 droplets per square centimetre. Coverage on the plots treated with the emulsifiable oil tank mix ranged from 4.4 to 12.0 droplets per square centimetre, which is light considering that the emitted volume was

Table 1. Dosages, meteorological conditions during spray application, and spray deposits of Virtuss applied against Douglas-fir tussock moth at Veasy Lake, Kamloops Forest District, B.C., 1982

Treatment	Tank mix	Dosage (PIB/ha)	Temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Droplet cm^{-2} ($\bar{x} \pm$ SD)
T1*	Oil	1.6×10^{10}	13.0	59	2	4.4 ± 2.5
T2	Oil	8.3×10^{10}	16.0	63	2	12.0 ± 9.8
T3	Oil	2.5×10^{11}	21.0	46	2	9.7 ± 5.5
T4	Aqueous	2.5×10^{11}	11.5	52	1	27.3 ± 9.0

*T, treatment.

9.4 L/ha (Table 1). No precipitation was recorded for 1 week after spray application; therefore no leaching of the virus from the needles occurred.

Egg-mass, larval, and pupal surveys. Spring egg-mass densities (Fig. 2) were greater than 0.7 per three lower branches on plots T1, T2, T3, and C1, C2, C3; noticeable defoliation would be expected if these plots were left untreated (Shepherd *et al.* 1984*a*). Plot T4, with a value of 0.52, was not expected to show noticeable defoliation and no survey was conducted on plot C4 as it was selected after eclosion and larval dispersal.

Egg-mass surveys conducted in the fall of 1982 (Fig. 2) showed that egg-mass densities in all treated plots were reduced from their spring outbreak values to endemic levels of 0.089 or less. In plots T3 and T4, which received the highest dosages of NPV, egg-mass density was 0.02. When Abbott's formula was applied to correct for natural mortality, reduction in egg-mass density attributed to treatment was 97% in plot T1 and 99% in plots T2 and T3. Egg-mass reduction in plot T4 could not be calculated because no spring egg-mass survey was conducted on its paired check (plot C4). The pre-spray population densities of Douglas-fir tussock moth larvae and the count taken 6 weeks after spraying are shown in Table 2, along with the population reductions. Applications of Virtuss in an oil tank mix gave population reductions of 65–95%; this suggests a direct

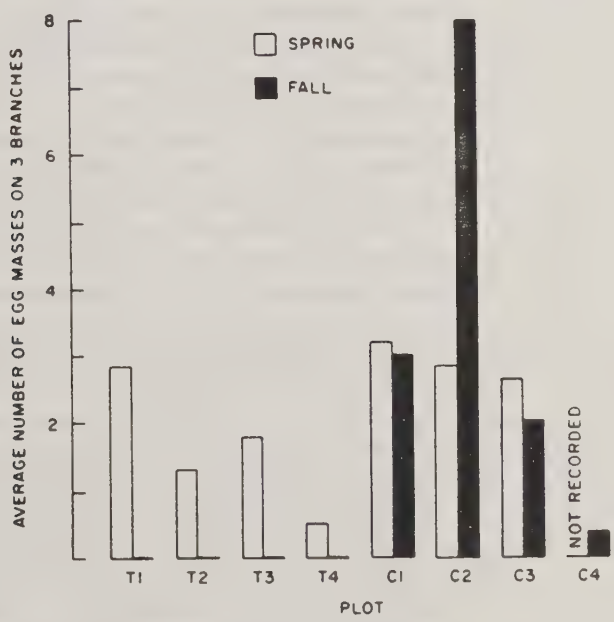

FIG. 2. Spring and fall egg-mass densities in treated and check plots at Veasy Lake, Kamloops Forest District, B.C., 1982. Values for fall collections were 0.089, 0.04, 0.02, and 0.02 for T1, T2, T3, and T4, respectively.

Table 2. Population densities of Douglas-fir tussock moth larvae in plots treated with Virtuss and in matching check plots at Veasy Lake, Kamloops Forest District, B.C., 1982

Plot No.	Treatment (PIB*/ha)	Tank mix	Larvae per m² foliage ($\bar{x} \pm$ SE) Pre-spray	6 weeks post-spray	Population reduction due to treatment† (%)
T1‡	1.6×10^{10}	Oil	182.8 ± 12.6	6.7 ± 1.8	65
C1‡	Check	—	197.5 ± 18.0	20.5 ± 2.9	—
T2	8.3×10^{10}	Oil	145.8 ± 12.2	2.8 ± 0.7	91
C2	Check	—	136.9 ± 9.4	28.7 ± 2.8	—
T3	2.5×10^{11}	Oil	302.0 ± 28.7	1.0 ± 0.4	95
C3	Check	—	360.6 ± 34.6	24.1 ± 4.6	—
T4	2.5×10^{11}	Aqueous	41.8 ± 5.3	2.0 ± 0.6	87
C4	Check	—	81.2 ± 16.5	28.9 ± 4.3	—

*PIB, polyhedral inclusion bodies.
†Calculated using a modified Abbott's formula (Fleming and Retnakaran 1985).
‡T, treatment; C, check.

relationship to dosage. The 2.5×10^{11} PIB per hectare dosage in the oil tank mix gave 95% population reduction, one-third of this dosage 91%, and one-sixteenth 65%. The 2.5×10^{11} PIB per hectare dosage in the aqueous tank mix with molasses reduced the population by 87%. The pattern of changes in larval population densities and NPV infection rates between 2 and 7 weeks after spraying are shown in Figure 3. Emergence from field-collected cocoons from treated plots T1, T2, T3, and T4 was 18, 4, 10, and 20%, respectively; those from check plots C1, C2, C3, and C4 showed 43, 28, 33, and 35% adult emergence, respectively (Table 4). The reduction in adult emergence due to NPV treatment, using Abbott's formula, ranged from 44 to 87%. The sex ratios of the emerging adults were inconsistent.

Virus impact assessment. From 73 to 89% of the larvae collected before spraying from the eight plots were successfully reared to adults (Table 3). Microscopic examination of larvae that died during rearing showed a low incidence of naturally occurring virus except in check plot C4 where 9.7% died from NPV. However, subsequent samples from this plot showed a lower incidence of NPV infection (Fig. 3), indicating that this sample, which was collected post-spray, may have been contaminated during handling. Microscopic examination of the larvae showed that the incidence of NPV infection in the treated plots reached a peak of about 85–100% of the larvae at 5–6 weeks after spraying (Fig. 3). In contrast, NPV in untreated check plots at 5 weeks after spraying only reached infection levels ranging from 0.7 to 10.3%. In the final sample taken 7 weeks after spraying, the highest infection level was 43.4% in C3. This was attributed to naturally occurring NPV. In the other check plots, infection ranged from 1.4 to 23.4%.

Percentage infection and development of an epizootic among the larvae in the four treated plots was directly related to dosage with the exception of plot T4. Although this plot received 2.5×10^{11} PIB per hectare, in the aqueous formulation, the epizootic developed slower than in the other three plots. This slower development was probably due to a lower initial Douglas-fir tussock moth population density. However, by 5 weeks after the spray, percentage infection in plot T4 was higher (97.7%) than in plots T1 and T2 (68.5 and 84.5%, respectively) receiving the reduced dosages. The results in plot T4 show that even at relatively low population levels (41.8 larvae per square metre) it is possible to cause a viral epizootic by application of Virtuss.

Defoliation survey. Although heavy defoliation was observed in most plots, a formal evaluation was not possible because of the light to moderate western spruce budworm population in some of the plots. However, Douglas-fir tussock moth larvae continued to

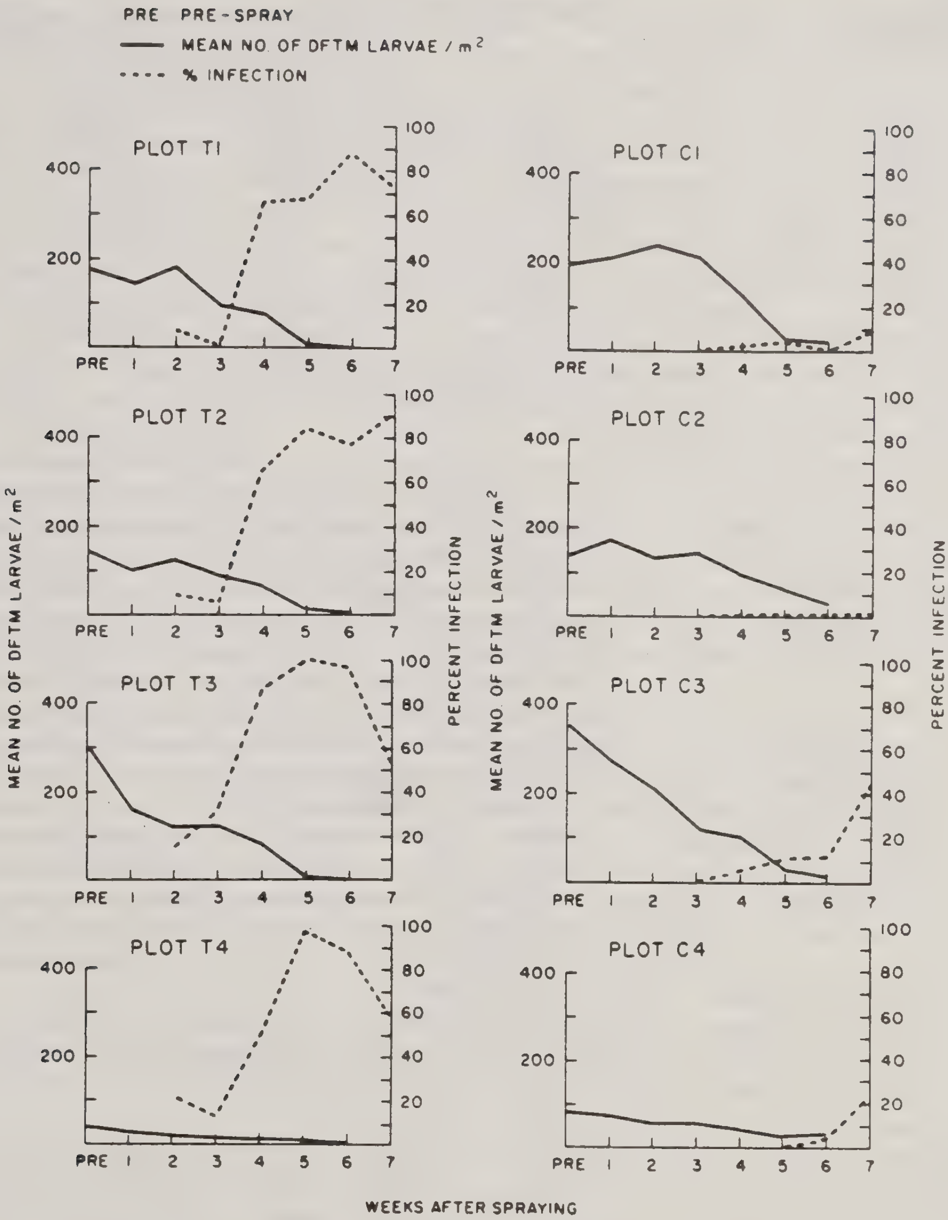

FIG. 3. Douglas-fir tussock moth larval density per square metre of foliage and percentage NPV infection of larvae following application of Virtuss on four treated plots compared with four matching untreated check plots.

feed for several weeks after the spray application. Except on plot T4, the current year's foliage was destroyed on many trees as well as most of the older foliage, with upper crowns particularly heavily defoliated. Plot T4 had an egg-mass density in the spring slightly below the outbreak threshold, whereas plots T1, T2, and T3 were well above this threshold. The apparent foliage protection in plot T4 was probably due to the low Douglas-fir tussock moth population and not the Virtuss treatment.

Table 3. Mortality of individually reared larvae collected before spraying from plots at Veasy Lake, Kamloops Forest District, B.C., 1982

Treatment	Total no. reared	% adult emergence	% Mortality by	
			NPV	Other causes
T1*	167	73.1	0.6	26.3
T2	172	83.1	2.3	14.5
T3	161	80.8	0	19.2
T4	168	82.7	0.6	16.7
C1*	175	89.1	0.6	10.3
C2	180	86.1	1.7	12.2
C3	170	87.1	0.6	12.4
C4	155	78.1	9.7	12.3

*T, treatment (for detail see text or Table 1); C, check.

Discussion

The amount of deposits recorded on Kromekote cards did not reflect the subsequent impact of Virtuss on the Douglas-fir tussock moth population. Two probable reasons for this are that the amount of spray reaching the foliage is not indicated accurately by the amount of spray on the cards and that secondary infection occurred among the larvae. Weekly microscopic examination of samples of larvae revealed NPV infection in about 10–30% of the larvae 2–3 weeks after spraying. When these larvae died, they ruptured and released massive quantities of PIBs onto the foliage. Secondary infection probably resulted from these virus foci and caused an epizootic that decimated the Douglas-fir tussock moth population. Douglas-fir tussock moth is an ideal candidate for control using a virus because it spends about 8 weeks in the larval stage. This allows ample time for the development of an epizootic if the virus is applied when larvae are in the early instars. However, if foliage protection is the principal objective, this may not be an acceptable strategy where high larval populations will completely defoliate trees before an epizootic can develop. To protect foliage, Virtuss should be applied before the Douglas-fir tussock moth population reaches outbreak levels. In most cases this would require treatment the year before defoliation can be observed; a population detection and monitoring system would be essential.

The emulsifiable oil tank mix and the aqueous tank mix containing molasses both gave acceptable results at a dosage of 2.5×10^{11} PIB per hectare. This dosage, originally recommended by the U.S.D.A. Forest Service, is also the dosage on the Virtuss label.

Table 4. Emergence and sex of adult Douglas-fir tussock moth from field-collected pupae from Virtuss-treated plots and check plots, Veasy Lake, Kamloops Forest District, B.C., 1982

Treatment	Number* of pupae reared	Ratio (males:females)	Adult emergence (%)	Emergence reduction† (%)
T1‡	107	5.2:1	17.8	58
C1‡	219	2.1:1	42.9	—
T2	108	1:1	3.7	87
C2	181	1:2.2	28.2	—
T3	105	1:2.3	9.5	71
C3	117	1:1.4	33.3	—
T4	52	1.5:1	19.5	44
C4	265	1.4:1	35.0	—

*Collection included some larvae that pupated shortly after collection.
†Attributed to treatment and calculated using a modified Abbott's formula.
‡T, treatment; C, check.

Present production cost of this dosage in Canada (at Sault Ste. Marie, Ont.) is about $50 (Canadian) per hectare. Virtuss at 8.3×10^{10} PIB per hectare in the emulsifiable oil tank mix (T2) gave a similar degree of control as the recommended dosage. If this dosage gives consistently good results, cost of virus material would be reduced to $17 per hectare. The lowest dosage, formulated and used in the emulsifiable oil tank mix, 1.6×10^{10} PIB per hectare (T1), had less impact than the other treatments when population reduction of both larvae and pupae was considered, but it was still markedly different from the untreated checks and reduction in egg-mass density was impressive at 97%. At this concentration, the production cost would be only $3.20 per hectare, but because experience with Virtuss is limited, we cannot recommend it for operational use at this dosage.

The adult sex ratio is usually 1:1 in Douglas-fir tussock moth (Wickman and Beckwith 1978), but changes of sex ratio in favor of males have been noted following NPV applications (Cunningham 1982). In many Lepidoptera and Hymenoptera, females pupate later than males giving females more time to ingest virus, become infected, and die. With six larval instars in the female and five in the male, this was expected to be evident with Douglas-fir tussock moth. However, a significant change in sex ratio, 5.2 males to 1 female, was found only in plot T1 which received the lowest dosage. There is an interesting discrepancy between adult emergence from the pre-spray larval samples from all eight plots reared in the laboratory, where emergence figures ranged from 73.1 to 89.1%, and adult emergence from cocoons collected in the four check plots, where figures ranged from 28.2 to 42.9%. Perhaps natural control factors, including starvation, reduced pupal viability in the field.

Fall egg-mass densities can be one of the most meaningful measurements of efficacy because one can use these values to predict population densities in the following year (Shepherd *et al.* 1984*a*). This survey showed high Douglas-fir tussock moth populations would occur on the four untreated check plots and low or endemic populations on all treated plots. Although plot T1 had the highest egg-mass density of all treated plots at 0.089 per three lower branches, we predict that this density will be below the damage threshold level of Douglas-fir tussock moth, based on the findings of Shepherd *et al.* (1984*a*). Hence, even the lowest dosage may have provided sufficient control to return the population to an endemic level.

Surveys were conducted in 1983, 1984, and 1985 on all the treated and check plots to determine virus spread, virus carryover, fate of the residual Douglas-fir tussock moth population on the treated plots, incidence of naturally occurring NPV in the check plots, and effect of the Virtuss treatment in terms of tree damage and mortality (Otvos *et al.* 1987). The latest outbreak of Douglas-fir tussock moth in British Columbia collapsed in 1984 and another outbreak is not expected until 1989 at the earliest. When it occurs, we intend to treat blocks (400 ha or larger) with Virtuss at 2.5×10^{11} and 8.3×10^{10} PIB per hectare to determine if the lower dosage found effective here is equally effective on an operational scale.

Acknowledgments

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REGION 5

As far as defoliators were concerned things were quite in the region with no DFTM or budworm problems. Our time was spent working on drought/bark beetle problems.

The only item of interest to this Committe is that in cooperation with the WO we have sumitted new toxicology data to California Dept. of Food and Agriculture to support the registration of TM-Biocontrol-1. The studies were:

- Acute Dermal
- Chomosome Aberration
- Primary Eye Irritaition
- Acute Pulmonary Toxicity
- Acute Oral
- Dermal Irritation
- Intraperitoneal Infectivity

This information was also submitted to EPA to support the national registration. We recommend that other regions submit this information to your states if such data is need to continue state registrations.

11/6/90
Julie Weatherby

Western Defoliator Report for Region 4

Gypsy Moth Eradication Project - Wasatch Front, Utah

Site: 20,000 AC in Salt Lake, Utah and Davis Counties.

Applications: 3 applications of Foray 48B, NEAT at 64 oz. per AC

Application Aircraft: 2 Jet Rangers 206 B3, 1 Hiller Soloy

Atomizers: Beecomists

Results: Significant population reductions have occurred in most areas within the spray blocks. The project successfully reduced the population to non-detectable levels in many area. These areas will be excluded from the spray project planned for 1991.

Plans for 1991 Project: The project objective will be to eradicate the population from the area. The project area will be approximately 22,000 - 25,000 Ac. Approximately 3,000 acres will be on State and Private Lands. The remaining acreage will be on Forest Service Lands.

Douglas-fir Tussock Moth Outbreak - Southern Idaho

Site: Approximately 35,000 AC of moderate to heavy defoliation has been detected on the Boise National Forest. Several other smaller areas of defoliation haven been detected on the Sawtooth NF, the Payette NF, State lands east of Bellivue, and on BLM lands in the Owyhee Mtns.

Pheromone trap catches for 1990 are extremely high across southern Idaho except for the trap sites on the Salmon NF.

Douglas-fir Tussock Moth Outbreak - Wasatch-Cache NF

Site: Approximately 2,000 AC of heavy defoliation of subalpine fir has been detected in upper Blacksmith Canyon. Little is know about populations in surrounding stands.

Western Spruce Budworm Defoliation - Salmon, Challis, and Payette NFs

Site: Approximately 41,800 AC of light to heavy defoliation has been detected on the Salmon NF, 800 AC of light defoliation on the Challis NF, and 9,200 AC of light defoliation on the Payette NF.

Ponderosa Pine Needleminer - Sawtooth NF

Site: Approximately 600 Ac of defoliation caused by the ponderosa pine needleminer has been detected on the Sawtooth NF in the Marsh Creek drainage.

Region 6 Report for the National Steering Committee on the Aerial Application for Western Coniferous Defoliators

1990 WESTERN SPRUCE BUDWORM SUPPRESSION PROJECT, YAKIMA INDIAN RESERVATION, WA

LOCATION: Yakima Indian Reservation, Washington

INSECTICIDE: Thuricide 48LV applied undiluted at a rate of 16 BIU's in 42.7 oz. per acre.

APPLICATION: Primary Applicator: Aero Tech, Inc., Bovina, Texas
Subcontractor: P.J. Helicopters, Red Bluff, CA
Fixed wing: 3 Air Tractors
Helicopters: 2 UH1B-20L
Observation Helicopters: 2 Bell 200
2 Hughes 500

ACRES TREATED: 70,827

COST: $15.35 PER ACRE

DISCUSSION: The Yakima Project was an operational project that was carried out on the Yakima Indian Reservation. Treatment began on June 20 and was completed on June 29. The terrain was characterized as gentle and rolling, with a few deep canyons. The project consisted of 3 treatment areas: Signal Peak, Simcoe West, and Simcoe East. Early larval densities qualified the units with 24 to 29 larvae per 45 cm. branch. Post-spray population densities averaged 1.7, 5.0, and 2.4 larvae per three 45 cm. mid-crown branch tips.

STATUS OF OTHER ACTIVITIES IN R-6

- A second year of follow-up sampling was done in the Meacham Pilot Project area. This area was treated in 1988. Although results for the sampling ar not yeat available, larval populations appear to have increased substantually. This area is being considered in a western spruce budworm environmental analysis being conducted by the Wallowa-Whitman NF for 1991.

- In cooperation with Roy Beckwith, PNW Station, a formulation of a carrier produced by ESPRO, was tested for TM Biocontrol-1. It appears to handle fairly well in the lab. The next step will be to test it in an aircraft system.

- Douglas-fir Tussock moth populations appear are increasing, especially in the vicinity of the Pine RD on the Wallowa-Whitman NF. Pheromone trapping, lower crown beating for larvae, and pupae/egg mass searches have been conducted in this area. Results are not available but indications are that there will be significant defoliation in 1991. The Forest is conducting an environmental analysis of 11 units on a total of 300,000 acres. There are indications from other areas within the Blue Mtns. that populations are also beginning to increase in those areas.